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STAR WARS AND BEAM WEAPONS

by

Hong Xingliu, Jiang Songchuan, Wei Zhiyong

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STAR WARS AND BEAM WEAPONS

Hong Xingliu Jiang Songchuan Wei Zhiyong (Trans & Ed.)

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GRAPHICS DISCLAIMER

All figures, graphics, tables, equations, etc. merged into this translation were extracted from the best quality copy available.

CONTENT SUMMARY

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Since U.S. President Reagan put forward the "Strategic Defense Initiative" (commonly called "Star Wars"), "Star Wars"has already become an important topic of world discussion. This book will explain for a broad readership the background of the appearance of the "Star Wars" plan, current and prospective trends, as well as the position and function of beam weapons in "Star Wars" plans, supplying a good amount of important reference material.

Beam weapons are a leading edge field in national defense science today. This book takes large amounts of (illegible) material and (illegible) images and figures (illegible) laser weapons, particle beam weapons as well as (illegible) weapons,and so on, and, (illegible) technology, carries out an introduction of profound fields in simple terms. Readers can obtain knowledge in a variety of areas, understanding (illegible) the history of the development of beam weapons, the current situation, and future prospects. Material, (illegible) neutron particle beam weapons, (illegible) principles, X-ray lasers, γ-radiation (illegible) also will (illegible).

The language of this book is lively. It is rich in enlightenment and can supply (illegible) readers with reading and reference.

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STAR WARS AND BEAM WEAPONS

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FORWARD

In 1980, the then presidential candidate Reagan (illegible)and the U.S. Defense Intelligence Agency Chief General Daniel Geleiemu (phonetic) first put forward the "High Frontier"strategy. In 1983, in a report written with its topic being the"High Frontier", it took the "High Frontier" and raised it to the level of a strategy "related to the life and death of nations". The "High Frontier Strategy" acts as an organic synthesis conceptualizing "cosmic defense" and the space industry. It systematically puts forward an overall strategy relating to future U.S. comprehensive development and utilization of outer space in all the areas of military affairs, economics, and science. The final objective lay in seeking domination of the whole world in the 21st century.

On 23 March 1983, President Reagan made the famous speech associated with the "Strategic Defense" plan (commonly called"Star Wars" plan). He required U.S. "scientists to set up a long term research and development plan" in order to "realize the objective of eliminating the threat posed by strategic nuclear missiles", "altering the course of human history". Once having given the speech, it gave rise to violent contention on a world scale.

The primary intention of the "Star Wars" plan is to set up in cosmic space a multilayered defense system in order to deal with Soviet ICBM attacks, and, with the presupposition of seizing this "high ground" of today's world in outer space, win strategic military supremacy over the Soviet Union. Execution of this plan will make peaceful outer space into a fourth battlefield beyond sea, land, and air, producing profound and far reaching effects on the world situation.

"Star Wars" plans involve such fields as high energy physics, astrophysics, computer science, sensor probes, as well as communications, and so on. It is a synthetic system associated with multiple fields of study and multiple technologies mutually permeating and crossing each other.It is different from the "Manhattan" project which developed the atomic bomb in those days, and it is also different from the "Apollo" project for landing on the moon. All its requirements for such things as technological comprehensiveness, tightness of system connections, information accuracy and timeliness are unusually strict. /iv

At the present time, the "Star Wars" project has already turned into a main topic of confusing world discussions. The weapons systems used in "Star Wars" also give people a kind of mysterious sensation. The key purpose in our writing this book lies in--from a technological angle--making a relatively comprehensive elucidation of the main weapons associated with the "Star Wars" project--beam weapons systems. Relatively detailed discussions are carried out on such modernized technologies as laser beams, particle beams, microwaves, electromagnetic guns, and so on, acting as weapons history,current situation, and direction of movement. Secondly, based on the "Star Wars" project producing profound influences on all such things as future politics, economics, military affairs,diplomacy, and so on, we will also make a simple introduction of the background of the "Star Wars" project, development trends, and the reactions of various nations to the project in question in order to make a broad readership have a relatively comprehensive understanding of "Star Wars". In this book, we introduced a fair number of the newest photos and materials published in books and magazines inside China and abroad. We hope that it will be a work which readers

welcome--holding the newest information, simple, clear, and easy to understand.

China is a peace loving Socialist country. We oppose new world wars, oppose the arms race between the two superpowers;protecting world peace is our consistent principle and position.We oppose taking the "Star Wars" project as a sign of upping the level of the nature of the arms race. We oppose a military struggle for and control of outer space, completely opposing an outer space arms race. At the same time, we should see that the presentation and implementation of the "Star Wars" project means--in fields of high technology--the appearance of a heretofore unseen fierce competition. All the various nations of the world, one after the other, set up and adjust their own counter measures associated with high technology fields. The "European Technology Consortium" and the "Eureka" project are proof. Facing this type of competitive situation, we must have a strong sense of responsibility and urgency, realizing as fast as possible the modernization of China's science and technology and promoting the modernization of industry, agriculture, and national defense. We think that compiling this book, to a certain degree, fills a gap associated with the introduction of China to the status of "Star Wars" technology. However, due to limitations on our level and time pressures, it is difficult to avoid errors and inadequacies. We welcome reader criticism and correction.

This book was primarily edited by Hong Xingliu. Additional editors were Jiang Songchuan (Chap. 2, 3, 7, 10, 13, 14) and Wei Zhiyong (Chap. 4, 5, 6, 8, 9, 11, 12). The book as a whole was checked and corrected by Hong Xingliu. In the process of compilation, we received the zealous assistance

of Comrades Shen Fengjia and Wang Sen (illegible), and we express out special thanks for this.

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CHAPTER 1 STRATEGIC DEFENSE PLANS /1

When discussing the Strategic Defense Initiative and beam weapons, let us look back at the historical background associated with President Reagan putting forward the "Star Wars" plan. In 1980, the national defense advisor to then Presidential candidate Reagan, running for his first term--former U.S. Defense Intelligence Agency Chief, Gen. Daniel Geleiemu (phonetic) put forward the concept of the "High Frontier". In 1981, Reagan had not been in the White House long, and, with financial help from the Heritage Foundation, Gen. Geleiemu (phonetic) organized the"High Frontier" research team. It was composed of over 30 famous U.S. scientists, economists, space engineers, and military strategists. Going through 7 months of meticulous research, the brain trust composed of these scholars put forward a comprehensive concept relating to the U.S. opening up and utilization of outer space. This was nothing else than the "High Frontier" research report formally shared with the world on 3 March 1982. If one speaks of "Great Trends" and "The Third Wave"--from the angle of future studies--predictions were made of world development trends. In that case, the "'High Frontier' Project" moved a step further from strategic heights and selected the overall direction of future U.S. development.

The "High Frontier" strategy primarily includes two parts--military and economic. These are nothing other than the "Star Wars" project and the conceptualization of space industry.

1-1 MULTILAYERED DEFENSE SYSTEMS

The formal designation of the "Star Wars" project is the"Strategic Defense" plan, that is, a plan for the setting up of multilayered defense systems in outer space. The basic assumption of multilayered defense is that the flight tracks of future incoming missiles can be divided into several phases. In different phases different defensive means are adopted. In this way, forward defensive layers are capable of reducing threats to defensive layers farther back. Rear defensive layers are then able to catch attacking missiles which have penetrated forward defensive layers.

The first layer is boosting period defense. The boosting period begins with the ignition of boosters. When rockets penetrate layers of dense atmosphere, they liberate large quantities of red hot gases producing strong infrared radiation and visible light. As a result, it is very easy to probe for them. With regard to missiles in rapid flight, the stage in question is generally sustained for 3-5 minutes. In this period,defense systems must probe for missile launch points, control centers, and the types of attacking missiles. After that,boosters must be rapidly destroyed. One small oversight in boosting period defense will carry with it quite disadvantageous consequences for the several following defensive layers.Missiles getting past boosting period defenses--in the post boosting phase--will release a number of warheads, including reentry vehicles and false targets. The second layer, that is,post boosting period defense, generally lasts 6 minutes. In comparison to the boosting phase, the post boosting phase battle preparation time is relatively long. In the initial post boosting period, missile mother modules release multiple individual warheads, flying, respectively, toward different

targets. Reentry vehicles, false targets, and other supplementary penetration equipment are also released at this time. Very obviously, hitting attacking missiles is best in the initial boosting period. The reason is that, relatively speaking, missile mother modules are expensive to build and comparatively fragile. The third layer is the orbital middle period defense. This is the main phase of reentry vehicle and false target flight. Speaking in terms of ICBM's, this phase will last 20 minutes. Although middle period defense system preparation time is very ample, the tasks are still quite arduous, however. These are primarily the distinguishing of true and false targets. This will produce great effects on the success or failure of the defense. The fourth layer is the orbital end period defense. The size of the defensive range is determined by the degree of defensive target hardening. The orbital end period refers to that period from reentry vehicles entering atmospheric layers to their hitting targets or being destroyed themselves. The period this lasts is very short. In this period, false targets will also disintegrate by themselves.The four defense layers are controlled by a unified battlefield management system.

The intention of the U.S. pursuing the Strategic Defense Initiative is the opening up of space as a fourth strategic realm besides land, sea, and air. They anticipate, by seizing today's military "high ground" in outer space, to win strategic military superiority over the Soviet Union. The U.S. carrying out the
"Star Wars" plan means that it has thoroughly abandoned the /3
"guaranteed mutual destruction" strategy which it pursued after the middle 1960's and replaced it with a strategy of "guaranteed survival". This transformation in U.S. military thought clearly shows that it has resolved that it must cast off the same situation of continued encirclement of the

Soviet Union and nuclear talks with them, and, in conjunction with that, carry out contests in military preparedness at higher levels, that is,through competition in the area of space defense weapons systems,overwhelm the Soviet Union. As far as how the U.S. has made a great decision like this is concerned, the reliance is on their preeminent position in the new technology revolution and superiority in the area of space technology.

On the basis of the original concept of the "High Frontier Plan", the space antiballistic missile defense system which the U.S. wanted to set up included: (I) land based, fixed defense systems: used to intercept Soviet missiles and protect U.S.missile launch silos. (II) Antiballistic missile defense systems: the first generation was composed of 432 satellites;the second generation was composed of lasers and particle beams.It is possible to say that it was precisely on the foundation of this basic concept that the U.S. drew up the "Star Wars" plan associated with kinetic energy and directed energy weapons deployed on land, sea, air, and in space.

As far as preliminary arrangements associated with the U.S.pursuing "Star Wars" projects are concerned, they were accordingly divided into four designated phases--that is: (I)basic research stage from 1985 to 1989; (II) system development stage from 1990 to 2000; (III) full deployment stage from 2000 to 2005; and, (IV) completed deployment stage from 2005 to 2015.In accordance with this, the U.S. government figured on completing this enormous project around the year 2015.Recently, Yabolahansen (phonetic)--on the basis of the status of progress--estimated that the projects in question will be completed 10 years ahead of time. Paul Nicaize (phonetic) considered that this project could only be implemented between 2020 and 2030. It is seen

from this that, in a period of 20-50 years from now, following along with the implementation of the U.S. "Star Wars" project, the leading position of nuclear weapons among all types of weapons will gradually be replaced by space weapons. It is possible to say that the transitional period from the nuclear age to the age of militarized space has already begun. In the history of the development of weapons, it will be an unusually huge change.

Since the promulgation of the "High Frontier Plan", the Reagan government has advocated the development of space strategies and their early implementation. In conjunction with this, during implementation, to make improvements day by day, a series of important measures have been adopted throughout already. For example:

(I) In July 1982, President Reagan promulgated an order setting out the main guidance for U.S. space activities, that is,one of the primary objectives of the U.S. space plan is the setting up of "cosmic defense".

(II) On 1 September 1982, the U.S. established Space Command, thereby "to lay the organizational foundation for those people who plan to challenge the Soviet Union in space".

(III) On 23 March 1983, President Reagan delivered the famous speech called "Star Wars", putting forward the strategic military objective associated with the U.S. setting up of space defense systems. To this end, he required U.S. scientists "to draw up a long term research and development plan" in order to

"implement the elimination of the threat posed by strategic nuclear missiles", thereby "changing the course of human history".

(IV) In June 1983, the White House ordered the establishment of a "defense technology research" team led by Folaiche (phonetic) and a "future security research" team led by Huofuman (phonetic) in order to facilitate study of the feasibility and consequences of the "Star Wars" project in technical, political, and diplomatic terms.

(V) After the two teams described above put forward research reports, President Reagan--on 6 January 1984--signed 119 national security directives. These directives ordered relevant authorities to rapidly start research on such space weapons as lasers and particle beams in order to destroy ICBM's attacking the U.S.

(VI) On 25 January 1984, President Reagan, in his once a year State of the Union address, for the first time, put opening up the "High Frontier" into national strategic objectives. At the same time, he ordered the construction of a permanent manned space station to be sent into space in 1992. This marked, not only militarily but also economically, the start of U.S.preparations to develop space. The space station possessed a military and civilian compatible nature.

(VII) On 21 March 1984, astronaut Gen. Thomas Yabolahansen(phonetic illegible) was appointed to take over the "Star Wars" project. On 15 April of the same year, he officially took office as the chief of the newly organized Strategic Defense Initiative Agency.

The "Strategic Defense" project acts as a great change in the history of weapons. It influences in different degrees the interests and security of other nations. With regard to this, a number of states have all officially or unofficially had reactions.

1-2 Soviet Reaction to the Strategic Defense Initiative

With regard to President Reagan's television speech of 23 March 1983, Soviet reaction was unusually strong.

On 27 March 1983, Pravda carried a talk of Soviet leader Andropov. He violently denounced President Reagan's suggestions with regard to developing missile defense systems.

In April 1984, Soviet space research institute chief Shagedeyev (phonetic), during an interview by a U.S. news agency,expressed criticism of the Strategic Defense Initiative: "We have made a detailed analysis of the Strategic Defense Initiative. We believe that, even if it is possible to set up this type of high priced defense system, it is also not possible to prove that it is safe without a flaw. It is always possible to use relatively low priced surprise attacks to perhaps defeat this type of defense system. One method is to increase the number of

attacking weapons...Space based defense systems will prove unusually unreliable...Our conclusion is that this type of system will disappoint its manufacturers. It will only be able to cause a new round in the arms race. In conjunction with this,it will cause a sustained strengthening of the development of first strike weapons."

On 5 May 1985, the Soviet Union's former national defense minister Sokelofu (phonetic) asserted in Red Star: "If the U.S.figures on militarizing space, and, in conjunction with this,destroying the currently existing balance, the Soviet Union has no other choice than to adopt countermeasures."

The counter measures he is talking about here are:

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(I) increase political pressure, particularly in the realm of international arms control talks;

(II) carry out propaganda and manufacture false intelligence;

(III) adopt military technology measures, making weapons systems which cause antimissile systems to lose their effect. Soviet leader Gorbachev, in a letter to U.S. scientists,stressed: "At present, nobody in the world is not concerned about the U.S. Strategic Defense Initiative. This is a very universal feeling. This type of plan will necessarily block dialogue between us. Let us make one point clear. The purpose of dialogue between us and the U.S. lies not only in wanting to stop the arms race on earth. Moreover, it includes stopping space

competition. The Soviet Union will not be the first to take weapons and put them in outer space and will also strive to make other nations--particularly, the U.S.--not take this fatal step.Otherwise, it will lead to raising the level of nuclear war and an even more insane arms race."

The Soviet Union treats "Strategic Defense" plans extremely seriously. In conjunction with this, it reacts violently. On one hand, it hopes--through diplomatic and propaganda offensives--to delay or destroy the "Strategic Defense Initiative". On the other hand, by contrast, they step up development of their own space anti-satellite and antimissile weapons systems, studying how to cope with new strategies, new means, and new weapons associated with U.S. space weapons. There are people who estimate that expenditures used by the Soviet Union in space projects every year reach 30 billion U.S. dollars. In December 1987, on the eve of U.S.-Soviet high level meetings, Gorbachev--exceeding all expectations--announced that the Soviet Union also had "Star Wars Weapons" and was also in the midst of carrying out this type of weapons research. This shocked world opinion. This was because the Soviet Union, right along, had adopted an attitude of violent protest toward U.S. "Star Wars" plans.

At the present time, the Soviet Union is in the midst of research and experimentation on various types of space weapons such as new models of combat satellites, spaceflight fighters, as well as lasers and particle beams, electromagnetic waves, and so on. New models of combat satellites are capable of attacking U.S. satellites at 40 thousand km high altitudes. Space fighters are not only able to attack satellites but are also able to attack ground

targets. Besides this, the Soviet Union has also made very great progress in the areas of laser weapon development as well as satellites and warheads to cope with laser weapons.Soviet scientists, right along since the late 1950's or early 1960's, have concentrated research on so called "pulse energy". In the four new technologies of "Star Wars": lasers, particle beams, microwaves, and kinetic energy systems, the first three must use "pulse energy". In September 1984, the Soviet Union launched the largest spy satellite. This satellite was launched by a special booster capable of escaping U.S. satellite tracking.It is said that the Soviet Union has already begun research on a"space mine" specializing in the destruction of U.S. space defense systems. This type of "space mine" is capable of suddenly enveloping U.S. space defense systems. After that, it uses conventional warheads to bring about their destruction. A number of observers think that the reasons for Soviet opposition to the Strategic Defense Initiative are:

(I) Soviet concerns that the U.S. will acquire decisive military superiority through space. They believe that even if it is a very bad defense measure, it is also capable of being a useful supplement to first strike strategic forces militarily,possessing very strong offensive characteristics.

(II) Soviet concerns that the U.S., through the arms race,will wear down the Soviet Union economically.

(III) Soviet fear of U.S. technology applications related to conventional war.

(IV) Soviet thoughts to fish for political advantage in propaganda associated with surface opposition to the arms race with the purpose of achieving a split between the U.S. and western Europe.

1-3 Western European Trends

Under the influence of the U.S. "High Frontier" strategy, on 17 July 1985, 17 nations of western Europe--through French President Mitterand--put forward the "Eureka" project related to the setting up of a western European technology consortium to match it. This plan was primarily for civilian use considering at the same time the development of technology for military use and overall strategy. Its primary contents were: computers and software, automatic systems and factories, lasers and new materials, communications and transport, as well as biological technologies. The purpose of this technology plan lay in making Western Europe maintain the position of "equal U.S. partner".Looking at this, western Europe was also thinking of taking a place in the industrialization and militarization of space.

I. British Position

From December 1984 - February 1985, during a visit to the U.S., British Prime Minister Margaret Thatcher expressed support for the "Star Wars" plan. However, the support was limited only to research aspects and did not include deployment.

On 21 March 1987, British Prime Minister Margaret Thatcher,during a Moscow meeting with Soviet leader Gorbachev, demanded that both the U.S. and Soviet sides publish their timetables for carrying out space defense research, at the same time, making guarantees, within a specific period, not to withdraw from the antiballistic missile treaty reached in 1972.

Madame Thatcher said: "We think that there can never be a complete defense against strategic nuclear weapons. However, we are not able, before the fact, to eliminate this point: defense is capable of making precious contributions to the maintaining of comparatively stable relations....there is no reason to take cuts in strategic nuclear weapons and link them directly with U.S.space defense research plans."

II. French Position

On 16 December 1984, French President Mitterand, in a television talk, expressed the thought that the "balance of forces" is the only guarantee of maintaining peace. In conjunction with this, he restated France's complete disagreement with the "Star Wars" plan for the militarization of space.Moreover, on 17 April 1985, he also announced the "Eureka" plan.He thought that participation in the "Star Wars" plan ultimately could influence France's own nuclear deterrent force, making France's independent nuclear weapons lose their role.

However, the French government now also thinks that participation in research work is profitable for France's utilization of beneficial military technologies in the areas of air defense and space reconnaissance systems.

French Defense Minister Jilaisi (phonetic) previously--for strategic and technical reasons--criticized strategic defense proposals. However, later, he changed his attitude and clearly expressed support for France's participation in this research work.

In researcn work, despite the economic value of strategic defense proposal contracts seeming not to be excessively large(illegible), the position, however, that it will strengthen ties between the scientists of the U.S and other countries is attracting strength from various companies. A few large French aerospace and national defense electronic equipment companies--after staying on the sidelines for several months--have already established ways of making up for lost time and are preparing to submit bids to compete for U.S. strategic defense proposal research project contracts. France is not only responding to U.S. strategic defense proposals. Moreover, it is putting forward its own "Sun God" and "Xilakusa-II (phonetic illegible)" military space projects,starting on the path associated with military conquest of space.People in Paris military circles have clearly indicated that expenditures in the defense budget used for this one space project reach 10 billion francs. Investment will be by stages right up to 1991.

The Sun God plan will make France possess its own observation satellite. It is estimated that the first observation satellite will be launched in July 1993.

Through "Xilakusa-II (phonetic)" satellites replacing"Xilakusa-I (phonetic)" satellites to carry out information transmission plans, it is possible for people to get in contact with military aircraft and nuclear submarines. However,"Xilakusa-I (phonetic)" satellites are only able to put people in contact with ground forces and surface ships. The first"Xilakusa-II (phonetic)" satellite will be launched in July 1991. On 21 June 1985, West Germany decided to support the French"Eureka" plan and not participate in the U.S. "Star Wars" plan in the name of the government.

The Italian attitude is cautious. In March 1985, during a visit to the U.S., Premier Kelakexi (phonetic) only expressed "support". At the same time, he demanded that the U.S. agree to talks with the Soviet Union before deployment and, in conjunction with that, continue to observe the 1978 (illegible) antiballistic missile treaty.

Other western European nations such as Norway, Denmark,Finland, and Austria all expressed nonparticipation in "Star Wars" plans. Holland and Belgium, by contrast, had warm attitudes.

1-4 Japan-U.S. Cooperation in Strategic Defense Initiative

As far as the cutting edge science and technology which the U.S. needs in order to develop Strategic Defense plans are concerned, the U.S. is sparing no effort to rope in Japan.

In October 1983, the U.S. Defense Dept. sent a special team headed by Maerkemu Jiali (phonetic) (former Deputy Defense Secretary managing scientific research) to Japan to investigate.On the basis of Jiali's recommendations, the U.S. Defense Dept.,another two times in succession, sent Dr.

Maikelamu (phonetic) to Japan to observe and study photo electronic engineering and millimeter wave technologies. Following that, U.S Defense Dept.Strategic Defense Initiative Agency Chief Yabolahansen (phonetic)and other relevant officials also made frequent successive visits to Japan. The reason for the U.S. thinking so highly of Japan is completely due to Japan's possessing certain key technologies in the Strategic Defense Initiative: for example, infrared remote sensing technology, pattern recognition technology, super computer technology, photo communication and millimeter wave technologies,and so on.

The Japanese government has also showed very great interest in the Strategic Defense Initiative. Once it begins, it will have a positive effect on the strategic defense plans of the Reagan government. During a reply in the Diet, Prime Minister Nakasone said that--with regard to the problem of providing technical cooperation to the Strategic Defense Initiative--an agreement reached between the two countries in November 1983 would be carried out and weapons technology supplied to the U.S.When necessary, it was also possible to consider sending technical experts. Japan's 1987 defense expenditures broke through 1% of GNP. This could not avoid making other countries feel concerned. This is also very good proof of the development of military technology.

1-5 Highly Effective Defense Systems

If one wants to think of making multilayer defense systems capable of supplying relatively reliable ballistic missile defense, it is then necessary to make them capable of effectively stopping large scale attacks by incoming warheads reaching targets. However, any one type of weapon, in its initial use, is not capable of unusual perfection. The systems in question are also like this.

Assuming the use of 20000 warheads to attack the defense systems in question (this number is twice the number of warheads the Soviet Union has to deal with in the U.S. strategic defense systems), in that case, there is only a penetration rate not exceeding 0.1-0.2%. That is also nothing else than a defense effectiveness rate exceeding 99.8%. Only with this is it possible to reach defense objectives. To this end, the entire system must operate with high efficiency. If four layer defense systems (including ground based and space based middle period systems) are totally independent of each other (that is, various layers [illegible] utilizing sensors and combat management computer systems entirely unrelated to each other) then the effectiveness rate for each layer must reach 80%. Only then is it possible to realize the set objective. If there is one layer of defense which loses effectiveness, then, the effectiveness rates of the remaining three layers must be extremely high. Only then is it possible to guarantee unusually low penetration rates.

Besides the basic constituent parts of systems, there is also a need to set up relatively large scale middle period and end period intercept systems. They should possess long range attack capabilities and relatively low manufacturing cost.Raising the effectiveness rates for the various

individual components depends on middle period sensor powers of discrimination, middle period electromagnetic weapons firing systems as well as the reliability of boosting phase interception, and other such factors (see Fig. 1-1). Selecting points of particular emphasis requires going through long periods of on-the-spot investigation and comparison. There is also a relationship to the development status of the technologies used. If traditional kinetic energy weapons using chemical rocket propulsion are capable of being used to hit targets, then,this type of weapon can be selected for use. However, at the present time, their speeds still do not reach 5-8 km/sec.Besides this, excessively long chemical rocket acceleration periods (many reach several hundred seconds) make them short on competitiveness speaking relative to electromagnetic emission systems. Electromagnetic emission systems will rapidly take projectiles and accelerate them to very high speeds, thereby being able to reach relatively large ranges to satisfy the requirements needed for boosting phase intercept. Not only is this the case, but, systems established on the foundation of electromagnetic principles--compared to lasers--possess even stronger capabilities. The reason is that space based laser optical components are very fragile.

With regard to the offensive, it is possible to hit certain specially designated targets. However, defensive systems certainly do not--beforehand--know (illegible) the targets /12
attacked. Therefore, even if there is very low effective penetration, it will also place heavy burdens on defensive systems. Assuming that the initial two layers of defensive systems (boosting phase and post boosting phase) possess 80% effectiveness rates, then, the last two layers of the defensive system will face 800 attacking warheads which slipped through the net. It is necessary to make each

interception system capable of protecting a large piece of U.S. territory. Only then will they be able to stop the enemy offensive at key points. Also, only in this way, is it possible to develop numerous other interception weapons. If each rocket range fan reaches the entire territory of the U.S., it is possible that 1000-2000 interception weapons would be able to achieve defensive objectives.

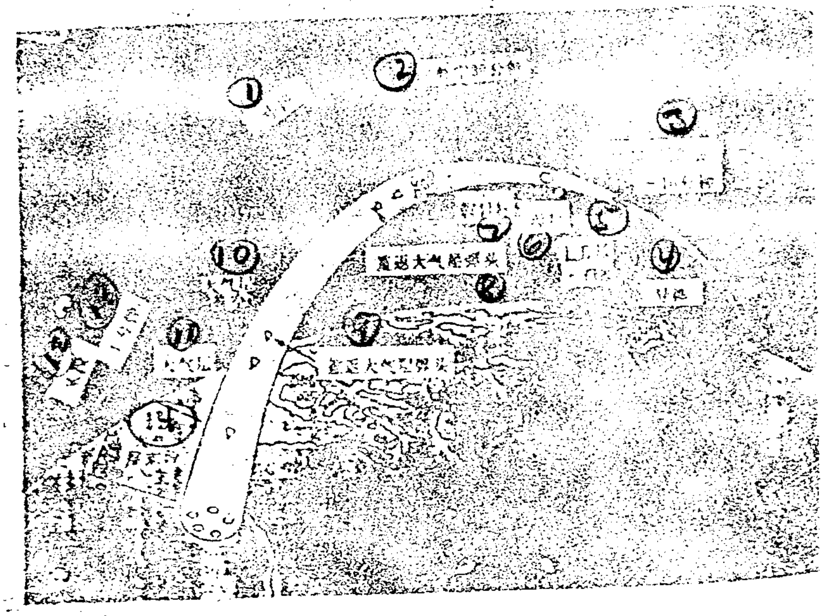

Fig.1-1 Multilayered Space Defense--Each Phase Represents a Corresponding Defensive Layer Defensive Area. These Phases Include Boosting, Post Boosting, Middle Period, and End Period.

(1) Middle Period (illegible)
(2) Outer Space 30 minutes
(3) Boosting, Post Boosting 10 minutes
(4) Missile (illegible)
(5) Ascent (illegile)
(6) Mother Module
(7) False Targets
(8) (illegible) Atmospheric Layer Warheads
(9) (illegible) Atmospheric Layer Warheads
(10) Atomosphere (illegible)
(11) Atmospheric Layer
(12) End Phase
(13) 1 Minute
(14) Atmospheric Layer End Phase (illegible_

Interception weapons associated with end period defense only have 100 km ranges. To protect the entire territory of the U.S.requires 400 fixed, land based defensive interception

points. Each point is capable of installing 10 interception weapons (total number 4000).
Relatively important launch points will also have high level /13
defensive capabilities in order to avoid encountering enemy offensives against important points. If middle period long range interception systems possess 80% effectiveness rates, then, there will only be 160 warheads for end period defensive systems to contend with. Despite the fact that the majority of defensive points only confront 1 reentry vehicle, in the final analysis, however, there are a number of defensive points which will face attacks from 2, 3, or even reentry vehicles. If one wants to reach full defensive objectives, at a minimum, 2 interception weapons must be arranged against each reentry vehicle in order to cope. With 4000 interception weapons, forward defensive systems then have no need to definitely all reach 80% effectiveness rates.

Considering close defense penetrations, presenting the conditions set out below with regard to defensive systems is required.

(I) To face all offensives, including those coming from enemy fast burning boosters, post boosting reentry vehicles associated with high speed development, and mother module high speed release of multiple warheads, it is necessary, in the boosting period, to only execute effective interception associated with reaching high levels.

(II) In the orbital middle period, faced with various types of concealment techniques (some can be recognized immediately and destroyed), accurate distinctions must be made between

heavenly bodies, false targets, and reentry vehicles.

(III) During placement in a nuclear environment and violent offensive, sensors must guarantee not to receive interference and be able to operate continuously.

(IV) With regard to a coordinated, across the board enemy offensive, space based systems must protect themselves or obtain the protection of other systems.

(V) With regard to enemy attempts at interference,coordinated across the board offensives, and nuclear environments, the communications networks associated with various individual systems must be highly effective.

1-6 Survivability

With regard to any ballistic missile defense system, space based and land based systems all must consider the problem of survival when met with enemy offensives. Faced
with enemy attacks, survivability is a necessary capability /14
for any equipment or system. It depends on the entire structure of the system and the actual status of the offensive. Survival rate requirements depend on policy makers opinions as well as the missions which systems carry out.

I. Land Based Systems

Land based systems include communication networks, command and control stations, land based interception weapons, terminal radars, land based sensors, land based laser emission devices and power supplies.

Land based systems must have adequate reliability and stability to complete their missions. Land based interception weapons are capable of using strengthening of mobile agility and increases in numbers in order to increase survival rates. Large model radars are capable of using the methods of hardening and the selection for use of relatively high operating frequencies in order to increase the capability to resist temporary loss of operation caused by nuclear explosions. Small model terminal radars are capable of being mounted on large trucks in order to increase mobility. Very narrow microwave beams are also capable of increasing radar resistance to interference.

Communication tools will opt for the use of various types of connection methods--for example, directional laser connections or other narrow beam connections, making them almost impervious to interference. Moreover, in nuclear environments, they possess certain resistance capabilities. Electronic instruments will be capable of resisting electromagnetic radiation produced by nuclear explosions in outer space. Command and control system scan utilize different operating methods (mobile stations and fixed combat stations) in order to protect themselves. The locations of airborne sensors are not fixed. As a result, it is possible to attain relatively high survival rates. It is also possible to consider additional antinuclear hardening measures.With regard to land based sensors, it is possible to increase their numbers. In conjunction with

this, it is necessary they be able to defend against high strength radiation produced by violent nuclear explosions.

Due to land based laser weapons being enormously expensive,it is very difficult, as a result, to increase their number.Also, due to their being, in war, very possibly prerequisite keypoint targets for destruction, it is, therefore, necessary to obtain a strong defense. If they (in normal circumstances) and other military installations meet with simultaneous attacks, they must necessarily be able to participate in the fight earlier,that is, initiate attacks against reentry vehicles in the(illegible) minutes before they approach them. In order to defend against cruise missile offensives, ground based laser weapons are capable of installation in the outlying areas of national territory, in order to facilitate discovering and destroying them before the cruise missiles arrive.
Ground based systems depending on high numbers, high /15
strength, and high agility, may be able to obtain quite high survival rates. However, this certainly does not mean that these systems are absolutely safe. It indicates only that they are able to survive long enough periods before they get commands and,in conjunction, complete missions. That is all.

II. Space Based Systems

In order to guarantee the survivability of the space based components of ballistic missile defense systems as a whole, it is, first of all, necessary to guarantee sensor and weapons security.

As far as the defense of space based systems themselves is concerned--in particular, the defense of sensors--there will be more problems than are confronted with ground based sensors. The reason is that satellites follow predetermined

orbits in flight (unless they are constantly adjusting their positions).Relatively speaking, it will then be easier for them to be attacked. If one knows beforehand their position at a certain given time, it is then possible to have an adequate period to make preparations to attack them, even to the extent of being able to destroy them before the outbreak of a large scale war. In war, space based sensors are very fragile. They are not only easily susceptible to the effects of nuclear explosions, but"blindness" or "temporary blindness". Moreover, they are particularly susceptible to lasers operating in the same waveband. Not only this, but ground based directed energy weapons are also capable of destroying their sensors precisely during observation or approaches to them (the sensors in question are used in observing these directed energy weapons or missile launching pads in the vicinity). Feasible countermeasures are to use large numbers of observation satellites in order to reduce potential losses.

With regard to direct enemy offensives, sensors and weapons also show weaknesses. These offensives include: nuclear attacks, kinetic energy attacks, laser attacks, as well as reflecting mirror optical condenser attacks, and attacks by physical or chemical means. These attacks can be launched from vertically ascending rockets or space based systems. With regard to attacks by space based ballistic missile defense systems, they are possible after their complete deployment and also possible during initial periods of deployment. In regard to the latter type of situation, ballistic missile defense systems are
unusually fragile. The reason is that they still do not /16
possess their own defense capabilities. Although the offensive side will pay full attention to the fact that this type of attack will lead to a war, and it is very dangerous to their own side; they,however, are even more aware that

ballistic missile defense systems, even though they have mid level defense capabilities,can also cause their nations to be threatened. Therefore, this type of risky offensive is also possible.

With regard to ballistic missile defense combat stations, it is possible to use large model shielding screens to carry out protection of them. However, this type of combat station might not be easy to conceal because of its enormous volume and excessively low orbits. In regard to sensor space stations,although there is a possibility of carrying out shielding,methods of concealment, however, can also be appropriately selected. One type of weakness associated with sensors lies in the fact that they must be exposed when executing their function during combat. Moreover, sensor satellites carry huge optical instruments and are then even more difficult to conceal and camouflage.

Space based reflector mirrors are used to take laser beams emitted on the ground or in space and reflect them toward targets. Relatively speaking, their survivability is not the same as other weapons systems. In periods of peace, reflector mirrors can be a help with certain shielding measures to avoid enemy surprise attacks and damage caused by cosmic dust.However, it must also be considered that normal testing and maintenance require taking down the shield covers. Due to space based reflector mirrors needing to guarantee high reflectivity and high optical precision, they are thus very fragile.

Various types of concealment methods are assistance measures in resisting enemy offensives. Because of this, the use of shields must be opted for under any circumstances. The reason is that surface coatings cannot stand up to corrosion associated with certain chemical substances (among these are

included rocket fuel). Therefore, outer shells must go through very good sealing. In meeting engagements with almost all rockets or"space mines", returning fire is more desirable than passive defense. No matter whether it is space combat stations or satellites, they should all possess self-defense capabilities. Using kinetic energy weapons to act as the means of returning fire is a very good type of defensive measure.However, it is only effective as long as the situation is one where kinetic energy weapons have a longer lethal range than the offensive weapons. Other loss producing techniques which we are now in the process of discussing, in the same way, possess the capability for lethal strikes. At the same time as investigating whether or not space based defense systems are capable of supplying their own protection (in particular, during initial periods of deployment), additional analysis should be done on a number of complicated factors. These factors include: specific values associated with the manufacturing costs of defensive systems and offensive systems, offensive and defensive tactics,lures, concealment, tactical feasibility, defensive system hardening, as well as offensive capabilities, and so on.

In the case of entire structures of ballistic missile defense systems which still do not exist, it is very difficult to precisely estimate ballistic missile defense system capabilities to protect themselves.

When there are only a small number of modules installed in space, it is a good opportunity for the offensive side. If ballistic missile defense systems deployed in early periods are not destroyed, it will take even greater risks. However, due to certain types of causes, with regard to restraining possible offensives against space modules of ballistic missile defense systems, this is only due to

threats of retaliation and all out nuclear war. The reason is that, no matter which side it is,when there is no defense system, nobody can set off a first strike nuclear offensive against another side.

In President Reagan's television speech of 23 March 1983, he clearly put forward beam weapons. In conjunction with this, he required the fastest possible development of this type of weapons system, making them capable of intercepting and destroying enemy missiles before they reach U.S. territory or U.S. allies. Although Reagan's speech did not expound a great deal on beam weapons themselves, after his speech, White House aides, however, provided supplementation: this type of system is capable of including the three technologies of lasers, high energy particle beams, and microwaves. Pentagon officials take the three technologies and refer to them altogether as directed energy weapons.

Reagan's so called "Star Wars" plan was certainly nothing new. It was nothing more than the first time this type of rapidly developing new military technology and strategic thinking had been approved from the presidential level. Early, at the end of 1982, the U.S. government had already spent close to 2 billion U.S. dollars in order to develop beam weapons. In the 1983 fiscal budget, the Reagan government had already put forward a February 1982 proposal. Finally, this proposal took the form of an amendment in Congress and passed at the end of the year. In conjunction with this, it was decided to appropriate 400 million U.S. dollars to develop beam weapons. However, this expenditure was most certainly not all used in order to develop ballistic missile defense systems. The Pentagon also looked for other applications of beam weapons technologies.

The Reagan speech made an announcement which immediately caused violent controversy. It seemed as if this speech had already put forward a complete plan in conjunction with which implementation was already thrown in. Democrats in Congress and the public

criticized the government's ballistic missile defense policies as dangerous and impracticable. Soviet leader Yuri Andropov called it "irresponsible" and "mad". /19

Just like the situation in the past, a new technology would necessarily lead to a new arms race. U.S. military heads (naturally, the Soviets were no exception either) all hoped that beam weapons would be able to make force strengths give rise to dramatic changes. Carrying out a defense against nuclear ballistic missiles will produce deep and lasting effects.Perhaps this type of defense could also be used in other areas.People very easily thought that beam weapons were capable of being used to counter satellites, aircraft, or missiles, that is,they could be used not only in outer space but in the atmosphere.They could also be used on sea and land. A new generation of weapons composed of beam weapons was confirmed to be more powerful than the various existing types of weapons (see Fig.2-1). But, a number of observers still thought that making beam weapons was a clear waste of money. In conjunction with this,they believed that it was very dangerous. It would destroy the current international balance of power.

Fig.2-1 Schematic of Outer Space Laser Weapon Attack on Satellite. In Reality, in Space, Laser Beams Cannot Be Seen (No Matter What the Size of the Wavelength Is). The Reason Is that in Space There Is No Dispersing Material to Make Laser Beams Scatter to the Location of Observers.

Pentagon defense plans require enormous financial expenditures. Although huge investments will have the effect of promoting the development of these new technologies, at the same time, however, they will also produce a number of problems. With regard to several among these problems, the Pentagon can use the pretense of national security to hide from them. However, it is very clear that there are some problems have not yet been resolved. The Pentagon's top research organization--the national high technology planning agency--set up two diametrically opposed research teams. One team thought that beam weapons were actually feasible. The other team, by contrast, thought they should discontinue the project. The Pentagon's hesitation was not without reason. However, it still gave rise to sharp criticism on the two sides: one group of people calling for development of the project as fast as possible; the other group of people, by contrast, firmly opposed.

The question had already gone far beyond beam weapon technology itself. It had already shifted to even larger questions related to areas of the arms race and military posture.There were also sharp disputes which clearly belonged to the political arena. Obviously, beam weapons will lead to an intensification of the arms race between the U.S. and the Soviet Union. Applications of beam weapons (of course, their primary use is in order to defend against missiles) will undoubtedly cause changes in strategic defense thinking. In conjunction with that, they will influence the lives of this generation of people and even the next generation. People ought to pay close attention to the role of beam weapons in military strategy, and,in conjunction with this, make every effort to have one integral concept in order to make correct choices.

2-1 Ideal Weapons /20

Military heads are all clear: the development of beam weapons means that an important stride has been taken in the direction of "ideal" weapons. So how do they figure they are ideal weapons? Ideal weapons should possess adequate energy to hit targets, and, in conjunction with this, they should make them sustain catastrophic destruction. In this one simple sentence are included contents in several areas. First of all, ideal weapons should accurately and without error hit targets, and, in conjunction with this, carry enough energy to guarantee target destruction. Second, they should be able to instantaneously destroy any target, including solid, huge, very distant targets. Of course, there is also a requirement for the manufacturing costs of ideal weapons to be as low as possible, making the burden of military expenditures not feel too heavy.

Projectile weapons--small arms, rockets, missiles, and so on--are not able to precisely fullfil predetermined tasks. Their speed, range, and lethality are all very limited.
They may possibly miss targets or, although they hit the /22
target, they still are not able to destroy it. All projectile weapons, when hitting targets, face one basic problem. This is nothing else than--during weapon flight--the target can move (this means the target can get clear of the shot). Moreover, the earth's gravity as well as air resistance are also capable of making weapons deviate off targets.

Directed energy weapons are not this way. Laser beams put out by high energy lasers reach speeds of 300,000 km/sec. Subatomic or atomic particles discharged by particle beam generators are also capable of being accelerated close to the speed of light. In conjunction with this, they carry

huge energies. With regard to conventional weapons, it is not possible to expect them--in extremely short periods of time--to discharge such large energies. However, directed energy weapons, at least theoretically, are capable of reaching this point. They are more powerful than small arms, artillery, missiles, and so on. Before directed energy weapons become realities, there are a number of basic problems which must be resolved. With regard to particle beams, the question that must be answered is whether or not--when they penetrate the atmosphere or outer space--strengths do not attenuate too severely, there are not overly large deviations in direction, and, in conjunction with that, they are able to satisfy military requirements. These core questions have already all been entered into the Pentagon's particle beam weapons program.

Recently, the U.S. has invested more time and financial resources in laser technology research than particle beams. However, there is still dispute over whether they can really act as a type of weapon or not. Initial tests clearly show that laser weapons are already capable of destroying helicopters and small missiles. At the present time, under continuous beam conditions, lasers associated with output powers of 2 megawatts have already manufactured. There are people who optimistically believe that lasers associated with output powers reaching 10 megawatts will very rapidly come out. Moreover, advances will also be made in such areas as tracking, aiming, and focusing.

Making laser beams into weapons still has a number of difficulties that must be overcome. Primarily, they are how to take recognition, tracking, and aiming phases and change them from laboratory demonstrations into actual systems. At the present time, lasers are still a huge, difficult to grasp system. They must conform to military requirements,

thereby making common soldiers capable of utilizing this type of system, which, at the moment, is still only capable of being operated by physicists. Pentagon officials must ultimately believe that, only in solving the problems described above, is it then possible for them to become a system possessing lethal power and associated with rational expenses.

/22

2-2 Weapons System Concepts

The definition of a weapons system is the key to understanding beam weapon functions. Laser and particle beam production systems, in themselves, certainly are not weapons. However, once people step into the path of this type of strong beam, they will then be injured or even killed. However, normal military targets will certainly not permit this type of "cooperation"--taking and obviously placing themselves under enemy fire. Generally speaking, it is first necessary to discover the target; after that, place beam irradiation on the target, and, energy must be appropriately concentrated in order to produce destructive effects. Besides this, one should also add, a system capable of completing the tasks described above. Only then is it possible for lasers and particle beam producing systems to turn into weapons systems.

A soldier is capable of completing one iteration of firing a rifle without careful thought: aim at the target, pull the trigger, the black powder in the cartridge produces an explosion, the bullet is propelled in flight toward the target. Soldiers can also see whether they hit or not. If not, it is possible to shoot again.

People in science fiction novels almost all use a type of futuristic weapon. As the space traveler Luke in "Star Wars", when piloting a space ship equiped with an excellent computer, people saw that he would rather believe in his own strength than rely on the computer. In the movie, it described him activating at the right time magical weapons and destroying the death star of the evil empire.

Among actual directed energy weapons, this task is completed by so called ignition control systems. Just as its name implies, the function of them is to control weapon ignition. They require extremely few people or basically no people. Ignition control systems, as opportunities arise, are capable of automatically searching out targets, guiding weapon aiming, command initiation, and releasing beams. Moreover, they are able to track adequately long periods in order to facilitate the release of adequate energy to destroy targets. Ignition control systems also must carry out corrections for atmospheric effects and geomagnetic effects because these two will make beam weapons deviate from targets. With regard to missile defense, these programs should be completed within a few fractions of a second.

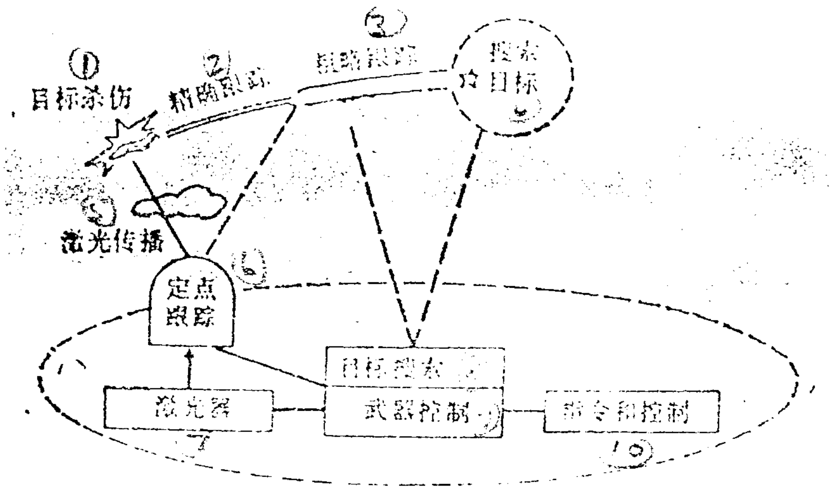

Fig.2-2 Basic Constituent Parts of Laser Weapons Systems Laser

(1)	Target Kill	(6)	Fixed Point Tracking
(2)	Precision Tracking	(7)	Laser
(3)	Rough Tracking	(8)	Target Acquisition
(4)	Target Acquisition	(9)	Weapon Control
(5)	Laser Propagation	(10)	Command and Control

However, only having an ignition control system is not enough. Weapons systems should also guarantee operating reliability in the strict military sense. That is to say, they should always be in a combat ready status. This means that beam weapons will activate on command, hit targets, and must be in an operational status in which they do not need to go through the strict training of specialists and constant adjustments. Besides this, system operation must be reliable. Due to environments not being those associated with laboratory conditions any more, but, under such bad conditions as being under enemy gun fire or in outer space orbit, reliability is thus very important. In this way, the difficulties which a system meets with in the area of engineering are very great. They are far greater than the problems of building a single system. Setting up a large laser or particle beam producing system is nothing more than

a relatively easy single part of the entire task. The public and publications often misunderstand this point.

At the end of 1973, the U.S. Air Force carried out a highly classified test: using high energy lasers, it hit and destroyed a flying target. It was carried out at Kirtland Air Force Base near Albuquerque, New Mexico. In April, 1982, at a laser and
electrooptics annual meeting, a declassified on site movie /24
recording was shown. The film was shown on the last day of the meeting. In the audience, there was a scientist from the Soviet Union. He was Danniliqifu (phonetic) of the Moscow Liebiejiefu (phonetic) physics institute. The movie convincingly demonstrated the test results: laser ignition, the appearance on the flying target of a bright spot (this was caused by infrared laser beam heating), and, following that, the flying target began to burn. Within 1 minute, it fell to earth. n It is certainly not possible--simply on the basis of one demonstration--to show that a weapons system is effective and practically feasible. In mid 1981, this type of situation occurred: after completing ground tests, overconfident officials announced at a February 1981 press conference that they had already finished planning in flight laser tests. A 400 kW laser was installed in a KC-135 aircraft. Both of the first two tests in June were failures. Lasers were not able to destroy targets-- air to air missiles. Air Force officials firmly believed that they had gotten a good deal of valuable information from the tests and certainly did not consider the tests failures. Reporters still did not buy it, putting out reports carrying headlines "Laser Weapons Fail Test". It made the public feel most puzzled, and the Air Force still carried out tests in secret.

News reports often obscure the strict boundary between lasers and actual laser weapons--in particular, those reports associated with a word or two of hearsay. For example, there were published reports that the Soviet Union planned to take high energy lasers and place them on space ships or the decks of warships. However, accurately speaking, they were only large lasers, not militarily meaningful weapons systems.

2-3 Weapons System Design

Weapons system design is a complicated problem which involves numerous factors. Precise designs must consider such areas as mission characteristics, utilization environments, as well as weapon type, and so on. With regard to beam weapons, their design should primarily consider the several points below:

(I) Target location and tracking capabilities.

(II) Beam power and quality.

(III) Beam directing capabilities (includes aiming and focusing particle beams and laser beams).

(IV) Beam transmission in air or outer space.

(V) Beam and target effects, including countermeasures adopted by the enemy as well as means of destroying enemy countermeasures

(VI) Confirmation of target destruction or loss of combat capability.

(VII) Reliability of weapons system operation.

(VIII) Utilization environment.

Each factor above must be considered in designs, and, in conjunction with this, give confirmed conclusions. Only in this case are beam weapons systems capable of executing their missions. As far as some factors are concerned--for example, beam power and beam quality--they are dependent to a very large extent on the characteristics and design of beam sources themselves. Several other factors--for example, beam transmission as well as beam effects on targets--primarily depend on physical mechanisms associated with beam effects on air and targets. Designs must all consider mission requirements--for example, target type and utilization environment.

Beam weapons can be divided into certain parts in accordance with different functions. Just as the U.S. Defense Dept. thinks, laser weapons systems can be divided into four subsystems. (See Fig. 2-2).

(I) Lasers (laser subsystem).

(II) Target Acquisition Systems (they confirm and track targets).

(III) Beam Control Systems (they direct beams, making them hit fragile parts of targets, and, in conjunction with this, must be able to carry out corrections on factors associated with the causing of beam divergence and deviations).

(IV) Ignition Command and Control Systems (they control operation of the entire system).

The details of particle beam weapons systems are somewhat different from this. However, they are generally the same. /26

2-4 Effects Caused by Beam Weapons

Modern weapons are all designed for specific purposes. There is no one type of weapon which is effective against all targets (from single soldiers to heavily armored tanks, from fast moving missiles and fighters to huge aircraft carriers, and so on). The idea that one single type of weapon is capable of satisfying various types of military requirements is unworkable. Beam weapons are also like this. Laser weapons associated with precision sensor components capable of destroying spy satellites are then powerless against nuclear warheads capable of enduring high powered radiation. Similarly, laser weapons suitable for use mounted on aircraft are then unable to satisfy requirements mounted on warships. The moisture resistance of ship borne beam weapons must definitely be guaranteed.

In accordance with traditional military classification, beam weapons are divided into two types--tactical and strategic. Tactical weapons normally are indicated for use against the weapons of opposition military forces concentrated in combat on land, sea, and air. The range of action is only a few kilometers more or less. Strategic weapons normally are used to destroy opposition military plants, city population concentrations or defensive systems used to protect enemy offensive strategic targets. Spy satellites, ICBM's, and long range bombers all belong to strategic weapons. Rifles, helicopters, short range missiles, as well as most combat aircraft all belong to tactical weapons. Nuclear weapons

can not only be strategic weapons. They can also be tactical weapons. Generally, high yield bombs belong to strategic weapons. However, nuclear bombs associated with explosive powers which are not large (for example, neutron bombs) belong, by contrast, to tactical weapons.

There are primarily three types of tactical beam weapon roles. At the present time, the Pentagon's main interest is mostly concentrated on lasers. The reasons are that particle beam technology and microwave technology are still far from being mature. In conjunction with this, they require huge equipment. Enormous volume is a fatal weak point unless used on large
warships. Speaking in terms of almost all tactical weapons, /27
lightness and convenience are critically important.

Ground Based Laser Weapons

Objectives pursed by the Army all think of taking medium power or high power laser weapons and installing them on tanks or other heavy armored vehicles. As far as Pentagon spokespersons talking about this are concerned, utilization of this type of weapons system is in order to protect "very high value targets". Taking tanks for an example, they include a number of systems and particulary complicated weapons systems and control systems. Ground based lasers, even under unusually bad conditions, are also capable, within a range of a few kilometers, of effectively showing results--including disadvantageous conditions such as the black of night, dust, smoke, as well as enemy attack, and so on. Laser weapons are capable of attacking any target besides heavy tanks so long as the target is moving in the forward area of the battlefield or flying over the battlefield. Laser destruction of targets can be realized through such methods as giving rise to mechanical damage, blowing up fuel or munitions, as well as destroying

sensitive components, and so on. Lasers are also capable of use in order to make soldiers' eyes temporarily or permanently blind or "stabbing" the bodies of soldiers through clothing. Of course, "stabbing" soldiers bodies requires very long durations in order to guarantee adequate laser energy to affect people's bodies. In the situation at the present time, if one wants to attain the objective of "stabbing" soldier's bodies, bullets are much cheaper.

Ship Borne Laser Weapons

The U.S. Navy is considering taking laser weapons and putting them on warships in order to destroy attacking enemy missiles. Using lasers to complete this type of mission is faster and more effective than conventional weapons. At the present time, the RHALANX gatling gun which is used is capable of firing 6000 rounds a minute. However, the Navy is still concerned that it will not be able to defeat lethal attacks from cruise missiles. If laser weapons are capable of operating in a wet environment, the compactness of their structures is certainly not key because aircraft carriers are so enormous. The Navy is also considering feasibility questions with using a number of charged particle beam weapons with combat radii of a few kilometers or shorter.

Airborne Laser Weapons

The U.S. Air Force is in the midst of considering taking laser weapons and putting them on aircraft in order to protect aircraft from enemy missile or aircraft attacks. At the present time, the biggest problem faced is volume and weight. Only mounting them on aircraft is it possible to exert the power of lasers to strike aircraft. The Air Force wants to take laser weapons and mount them on fast and agile fighters, allowing them to deal with bombers. Normally, bomber fuselages are relatively large in volume. Air speeds are relatively slow. Airborne lasers have effective

distances that will exceed 10 km. This is because, in the air, it is easier to discover targets than on the sea or land.

Due to specially designated tactical needs, each service has different requirements for laser weapons. The coordination work is carried out by a general office organization. Air Force General Robert Lankaina (phonetic) is the person in charge of this organization. This organization is responsible for the work of coordinating the several areas of laser, particle beam, and microwave technologies.

Antisatellite Laser Weapons

As far as satellites in military applications are concerned--in particular, applications in such areas as reconnaisance and observation of the status of arms control implementation and long distance communications-- they are made into a potential military target. Due to the fact that the sensitive electronic eyes of optical and infrared spy satellites are unusually fragile, they cannot withstand strong optical irradiation. Because of this, they are easily destroyed by lasers. Other models of satellites are also like this. At the present time, the U.S. Air Force is ardently serious about taking antisatellite laser weapons and entering them into new weapons system projects. Laser weapons are capable of installation on the ground, aircraft, as well as in outer space orbit. Each situation has its good and bad points. Beam weapons are being considered for use in order to protect their own satellites, making them avoid enemy attack.

Nulcear Defense Laser Weapons

What most attracts attention about lasers or say is the most satisfying thing militarily is that they are capable of destroying enemy missiles and bombers, capable of

intercepting them before they discharge nuclear warheads. This measure is capable of realization through such means as orbiting laser stations or utilizing reflecting mirrors on satellites to reflect high power laser beams put out by lasers on the ground. There are some models of particle beams which are also capable of use on orbiting combat stations. However, current technology is far from mature. Requirements for these weapons and requirements for tactical weapons are different. Even if they have already been idle for very long periods, after receiving commands, however, they must immediately ignite and fly to a target more than several thousand kilometers away. Light weight is very important to both orbiting combat stations and "satellite reflectors".

Strategic Area Defense /29

Protective networks composed of high energy lasers or particle beam weapons are capable of making hardened military targets avoid nuclear attacks. The defended targets can be missile launch silos or military bases. Before warheads fly to the defended target, beam weapons should be able to destroy them one after the other--making warheads lose their effectiveness or explode in places sufficiently far from targets in order to prevent nuclear warheads from destroying the military tagrets in question.

2-5 Revolution in Defense Strategy

Very large obstacles still exist to the development of beam weapons. This is primarily because the risks in this are too great. Orbiting antimissile combat station plans from science fiction novels can be considered to be a revolution in defense strategy. Some people think that the human race has already lived 20 years in a fragile balance of nuclear terror. What is called nuclear terror here is the so called "mutually assured destruction". This type of balance is based on the presupposition that there is no effective defensive means. If one side carries out a nuclear attack, the other side will also carry out a destructive counterattack--across the board nuclear butchery, true to its name, will be unavoidable. Based on this analysis, it was believed that no one could win in an all out nuclear war.

Opponents of beam weapons warn that the most dangerous thing lies in beam weapons being able to make nuclear wars have winners, that is, the side having beam weapons can defend against nuclear attack. Moreover, it is possible to initiate an attack against another side and not be punished. Critics also list other dangerous situations: even if beam weapons are not put to any use, they will still destroy the balance of power. For example, one side will be able to initiate attacks on beam weapons systems under construction in outer space, making them have no way to exert their effects. This type of attack will gradually escalate and could possibly lead to a Third World War.

Beam weapons supporters put forward a number of other view points. Among them, the most powerful opinion they believe is that beam weapons systems are capable, for the first

time, of giving the initiative in the balance of power to the defense.

]Because of this, it will end the phase of fragile peace /30
achieved by nuclear terror. Several days after the announcement of ballistic missile defense technology proposals, President Reagan said that the U.S. would, in the end, be able to supply this type of technology, and, in conjunction with that, made clear to the Soviets that "there would be no more need to keep offensive missiles". Beam weapons supporters latched on to this point, vigorously advocating that "Beam weapons are feasible technically. Their appearance is unavoidable. The U.S. should take the lead in mastering beam weapons in order to avoid being blackmailed by the Soviet Union." They asserted that this type of new technology has already made the "mutually assured destruction" strategy obsolete.

2-6 Beam Weapons and Arms Control

It should be said that the development of tactical beam weapons is an important step in the escalation of battlefield weapons. However, beam weapons that are used to counter ballistic missiles and satellites violate currently existing relevent treaties. The antiballistic missile treaty signed in 1972 points out that it is forbidden to deploy anitmissile beam weapon systems, and it is forbidden to utilize antisatllite weapons to destroy reconnaisance satellites. Of course, treaties certainly do not limit the development of this type of weapon.

Treaties are revised and interpreted by people. They can also be torn up. It seems that the Reagan government is certainly not satisfied with the antiballistic missile treaty. It has already gone through the execution of

discussions on anitmissile systems to defend MX missiles. In conjunction with this, they hope to revise the antiballistic missile treaty.

Beam weapons are an extremely complicated system. In order to give readers a comparatively comprehensive understanding, later sections of this book will introduce them in relative detail. Below, we will first talk a bit about weapon killing principles and a historical summary associated with beam weapons. After that, we will introduce technological principles in an easy to understand way , and, finally, talk some about military applications of beam weapons.

2-7 Weapon Killing Principles

Strategic Defense Initiative agencies are in the midst of studying the appropriateness of many types of weapons. /31
Directed energy weapons are considered as the most marvellous type of weapon known to man. Even though this type of weapon is only one potential part of strategic defense plans, they have the possibility, however, of becoming a core component of defensive layers. Their advantage is very clear. Killing energy transmission is carried out at or near the speed of light. With regard to classical ballisitc missile defense distances, the times for reaching targets are smaller than 1/10th of a second.
In this field, weapons being studied include several models of lasers and particle beam weapons. As far as utilization as weapons is concerned, the indicator used to determine the feasibility of different technologies is using minimum times to hit targets. Another consideration is--after hitting targets-- estimates of kill capabilities. The latter is partially determined by the target. This type of target can

be booster rockets, post booster rockets, or reentering missiles. Enemy satellites are also possible targets.

The three types of killing principles which can be produced by directed energy weapons are:

(1) functional kills;
(2) thermal kills;
(3) shock kills.

Functional Kills

Appropriate to particle beam and laser weapons, they can cause offensive weapons to lose their effectiveness. However, it is not certain that they will destroy them. Subelectron particles possessing several hundreds of millions of electron volts of kinetic energy are capable of penetrating at least several centimeters of dense material or several centimeters of aviation materials. Because of this, the sensitive electronic components inside targets will be damaged or destroyed. Moreover, seen from the outside, it cannot be immediately recognized that they are damaged. This type of kill is called a soft kill.

Thermal Kills

If one wants to make booster rockets lose their effectiveness, one looks for energies of 1-100 thousand Joules accumulation per square centimeter. Moreover, energy transmission must be unusually rapid. If energy transmission periods are unusually long (more than several hundred seconds), then, areas affected by heat reception will be able to have adequate time to make most of the energy be lost by conduction methods.

With regard to a given target, actual lethal energy values are determined by a number of factors--including such things as material types, surface properties, and mechanical

stresses. This energy will make surface temperatures rise, making the target object lose its effectiveness or deform. Internal forces associated with the target will make target objects suffer
catastrophic destruction. This type of kill hinges on power /32
levels obtained, weapons focusing capabilities, as well as distances to the target, and so on.

Shock Kills

These do not use thermal energy to kill targets but strong surface pulse waves produced when energy accumulates. This mechanical shock wave damages or destroys targets.

2-8 Science Fiction and Reality

Directed energy technology is a type of high technology which has recently appeared. However, the idea of using converged light waves to irradiate and destroy objects was around very early. In an ancient Greek legend, just this idea appears, even to the point of already going into practical applications. In the last century, science fiction novelists carried on this idea. In conjunction with this, they worked out the conception according to their own needs. Of course, there are some fabrications which make people not know whether to laugh or cry and are not convincing.

In the last twenty or thirty years, military people have also picked up the beam weapon dream. In this period, technological development grows more mature by the day, making the idea of beam weapons turn into more of a reality. In the past, a number of tentative plans still did not attract that many people. It was very clear that, at that time, technology would still not allow them. However,

today, President Reagan and Pentagon officials believe that the time is already ripe. The U.S., at the end of the 1983 fiscal year, had already spent 2.5 billion U.S. dollars in the area of directed energy weapons systems. Before the 23 March 1983 speech, the Reagan government suggested using a 1984 expenditure of 500 million U.S. dollars on directed energy research.

Even looking from the Pentagon, the expenses for taking this tentative plan and turning it into reality are still too large. It requires every American--man, woman, child, old or young--to shoulder a burden of 10 U.S. dollars. Currently, progress on this plan has already slowed down. The reason is that certain key technological questions still await resolution. There are still a number of problems on hold and not yet resolved. This is a plan associated with controversy right along. A number of critics believe that the sluggish style of work of officials blocks the project's progress. Other people, by contrast, say that the whole effort is a waste of money. Up to now, the debate is still not concluded.

2-9 Ancient Greek Legends

/33

Speaking of directed energy weapons, it is possible to trace them back to the ancient Greek period. Legends of the Greeks say that Zhousi (phonetic)--the king sent by God--possessed an enormously powerful weapon, that was nothing else than the beam weapon of the natural world--lightning. The Greeks were the earliest to recognize that sunlight possesses energy. In mythological legend, it records a person called Icarus. He had a pair of wings made of feathers and wax, and he could fly. However, when he flew close to the sun, because he was too close to the sun,

the sun made the wax melt. Finally, he fell into the sea and drowned. The Greeks also, early on, had the idea of destructive effects produced by convergent solar energy. A playwright-Yalisituopan (phonetic)--who lived around 400 B.C., in a play called "Clouds and Mist", describes the process of using convergent sulight to burn a locked up document.

The most interesting case of the Greeks making use of solar energy is perhaps the story of Archimedes blocking the Roman occupiers in Syracuse. Archimedes led the people of Syracuse to use a number of polished mirrors, taking sunlight and reflecting it on enemy ships anchored in the harbor, making the ships--made of material which burns easily--catch fire, and, proceeding with the next step, burning the ships up.

It is recorded in ancient books: Archimedes took a piece of hexagonal plane mirror, and, in conjunction with that, at an appropriate distance, also placed a number of quadralateral mirrors. Through metal alteration plates and hinges, it was possible to change the positions of these mirrors. Using this system, it did not matter whether it was summer or winter, at noon, it was always possible to gather radiation from the whole sun on them. In conjunction with this, sunlight was taken and re-reflected out. This type of light ray is unusually strong. Shined on ships, even if they were an arrow shot away, it was still possible to reduce them to ashes (see Fig.2-3).

It is too bad that this type of ancient beam weapon was certainly not capable of blocking the invaders. The city in question, in the end, still fell into Roman hands. Archimedes was also killed. Tradition says that, after the

Romans entered the city, Archimedes was still doing
calculations on a
mathematical problem. Roman soldiers wanted him to stop /34
calculating and follow them. Yet he did not pay attention.
The enraged soldiers then killed him. This story has
circulated widely right along. Archimedes has been
described as a hero of genius.

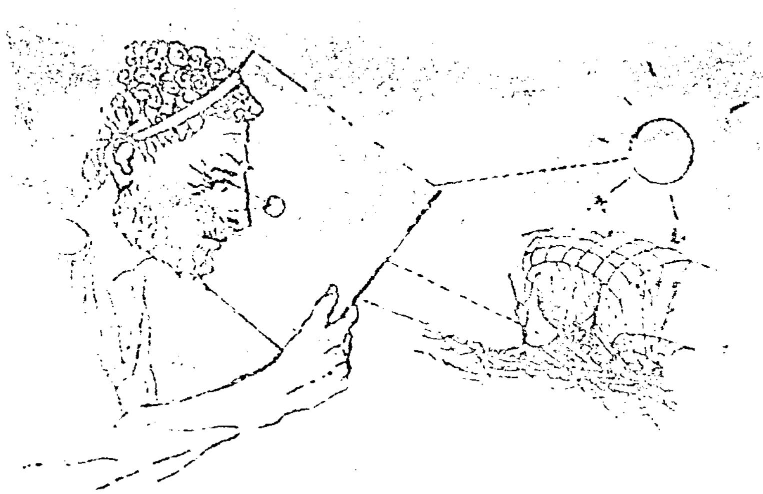

Fig.2-3 The Method Used by Soldiers Defending Syracuse to Aim at Roman Ships on the Coast Was: Bore a Small Hole in the Center of a Mirror. Looking Out from the Small Hole, It Was Then Possible to Aim at the Target. Tests Already Clearly Show that Large Enough Numbers of Soldiers Using This Type of Mirror to Aim Can Make Easily Combustible Material Reach the Ignition Point, Thus Making the Ship Catch Fire.

A number of observers hold a doubtful attitude toward the story described above. In the book "Ancient Engineers" by Sipulage D. Kaimupu (phonetic), it is asserted that, in that period, it was not possible to make such huge plane mirrors. Moreover, it was difficult to make light rays stably irradiate a target.

In the magazine "Applied Optics" in 1973 and 1974, there were articles in succession expressing doubts about the Archimedes legend. "Applied Optics" magazine is an authoritative magazine published by the U.S. Optics Society. Albert Klaus (phonetic) of the physics department of Loyola Univeristy in Chicago, in an article, said that Archimedes perhaps could organize several hundred people holding metal plates and
simultaneously throw sunlight on a target. However, /35
refuters immediately said that this idea is not practical. After a few months, another article pointed out that using plane mirrors in order to make objects burn, in reality, was accomplished by the French scientist D. Pufeng (phonetic) in 1747. He used 168 mirrors set in an array. Each was 8x10 inches. The experiment was carried out on an early spring morning. Using this system (actually, it may not have been necessary to use this many flat metal plates), at 46 meters, it was then possible to take a piece of thick wood plank and set it on fire.

A few weeks after the doubtful article above was published in "Applied Optics" magazine, the Greek scientist Yuenisi Shajisi (phonetic) made another demonstration. He gave 60 soldiers one 3x5 inch mirror apiece. Using these mirrors to converge sunlight, they ignited a wooden boat over 50 meters away. However, doubters gave their attention to a number of ancient writers who certainly did not refer to this incident, bringing up whether or not the ancient Greeks at that time were capable of making this type of mirror in order to realize ignition. We will perhaps never know for sure what actually happened at Syracuse 2200 years ago. However, the stiring plot of the story as well as its age old circulation are enough to explain how this tale attracts people. It tells us that, very long ago, the human race recognized the power of directed energy. Scholars of

military science right along have dreamed of building this type of powerful weapon. At the same time, it also calls peoples attention to the fact that the only method for proving whether or not this type of weapon is feasible is experimentation.

2-10 Wells and Thermal Radiation

In the last two thousand years, directed energy weapons became unkown to the public. Military people believed that they were only weapons in mythological stories. Right up to the 1890's, it was only then that the concept of beam weapons was brought up again by the pioneer British science fiction novelist Wells. In his book "War of the Worlds", "Martians" utilize a type of so called "thermal radiation" weapon to invade the earth. This book was published in 1890. The work has a clearly /36 Victorian style. At the same time, it contains a new thinking. Wells' description of "thermal radiation" weapons is quite farsighted.

It was really unthinkable, "Martians" being able to easily strike and overthrow earth people. A good number of people pretended to do serious textual criticism believing that they could produce very strong thermal beams in a type of specially insulated cavity going through certain methods. The "Martians" made use of a type of parallel thermal beam emitted by parabolic reflectors of still unknown construction, firing on targets selected beforehand. However, there was no one who could describe them in detail. What could be confirmed was their basic nature as heat rays. They did not seem like visible light. Heat is invisible. "Heat flow" moves like water. When combustible material contacts it, it then catches fire and burns. It can cause iron to become soft. It makes glass crack and melt. When

heat flow meets with water, the water immediately changes to steam.

Reading this story made people feel that Wells' ideas led in a new century. Compared to the sight of today's high energy infrared laser operations, his description of invisible heat rays--then called "thermal irradiation"--bears startling similarities to modern infrared laser weapons. Their destructive mechanisms are unusually similar to his conjectures. This is really an amazing prophecy.

Sixty years after Wells wrote his "War of the Worlds", real lasers came out. They are extremely similar to Wells' descriptions of "heat beams". In a forward he wrote for a 1962 reprint of "War of the Worlds", the science fiction novelist Yase Kelake (phonetic) said that " 'beam weapons' still only exist on paper. Right up until recently, it was still this way. However, this sort of situation will not be maintained too long. Assuming that you have still not heard of infrared lasers, I think you will very quickly know about them."

Wells is a wonderful writer. The secret of his works is taking enchanting imaginations and combining them with reality in this way--even today, he is still worth a read. It can be said that the book "War of the Worlds" is the first detailed description in a science fiction novel of highly mechanized weapons and their effects in attacking cities.

2-11 The Ray Gun Era

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In the U.S., in the 1920's and 1930's, science fiction novels had already become a literary genre. Today, that period is called the "pulp" period. Magazines in that era were all printed using bad quality paper. They could not be stored very long. Now, they may have all become paper scrap. Despite the fact that Wells lived right up to 1946, he does not, however, belong to that period. Viewed from today, the works of Wells, compared to most of the science fiction works of the 1920's and 1930's, have more reading value. His descriptions of technological details seem more believable (see Fig.2-

Fig.2-4 (long illegible caption)

Figure 2-4 (illegible)

At least, speaking in terms of beam weapons this is not clear about the basic nature of heat flow. Obviously, this type of weapon more resembles artillery than hand guns. Compared to this, the science fiction novelists of the "pulp" era let the heros in their works be equiped with hand held type ray guns or "death rays". The power of weapons in this type of science fiction novel normally is not restricted by physical laws. Once people contact this type of mysterious ray, they are scared out of their wits, or get sick, or die. In accordance with this type of weapon, the actual situation in the predicted future has no significance. The "pulp" era writers ofter take the development trends associated with a certain thing and excessively exaggerate them. Thus, it is not possible to predict genuinely valuable things. If their novels accurately described the situation in the 1980's, then we should all be flyers operating helicopters equiped with vaccuum tube equipment. Of course, due to the limitations of aviation technology, we are not yet that kind of flyer.

Ray guns have already become a standard prop in science fiction works. Although, in the last 50 years, there has been very great progress in technology, and, science fiction works as a branch of literature have seen great changes, modern authors, however, have simply taken the outer forms

of ray guns and changed them somewhat. That is all. Due to the exagerations of the writings of authors, beam weapons have become unusually mysterious. Now the standard terminology is "destructors". Very seldom do writers use the term "laser".

2-12 Origins of Directed Energy Technology

Just when science fiction novelists' imaginative powers were galloping far and wide, the early period of research work associated with beam weapons had already begun in reality. Those products, such as high energy lasers, particle beams, and strong microwave beam operations, were respectively carried out in different fields. Today, due to their all being able to produce high energy beams, in conjunction, they are used in order to effect targets and have been formed into one field.

What is interesting is that the cutting edge beam weapon /39 technology of the present age--in a certain sense--can be said to be very old. At just the same time that Wells wrote "War of the Worlds", Marconi was in the midst of studying the characteristics of radio waves. They built radio wave generating equipment with greater and greater powers. This equipment was first of all used for wireless transmission of messages. Somewhat later, it was used in commercial radio broadcasts. Finally, physicists and engineers began to consider other applications besides communications. In the early 1930's, there appeared the idea of using radio waves as weapons. The British government sent Sir Robert Wosen (phonetic)--Watt (radio technology pioneer) a memo asking him whether or not it was possible to make a type of electric wave weapon to be used in order to deal with aircraft. However, the answer was negative. In that era,

the power of electric wave generating equipment could not even reach levels to heat up human bodies or, going a step further, make blood pressure rise.

However, before this, Wosen (phonetic)--Watt had still had another idea. In the first few years of the beginning of this century, he had right along been studying the use of radio waves in order to precisely determine the location of lightning. He realized that it was possible to use radio waves to probe for enemy aircraft. This idea led to the appearance of radar. Ten years later, during the period of the Second World War, radar played a key role.

Radar technology attracted many researchers. People discovered that, when wave lengths were shortened (or frequencies increased), the probing precision increased. When power increased, sounding range also increased. Improvements in radar systems led to the appearance of high power radio wave generating equipment. Moreover, it raised the frequencies of radio waves. Wave lengths shifted from meter waves (corresponding to frequencies of 3x103 Hertz) to centimeter wave bands (frequencies of 109 Hertz, centimeter wave band electric waves are also called microwaves). Research was maintained for some years on systems for producing radio waves of even higher power and even shorter wave lengths--right on until unusually high powers were achieved. This sort of high power caused military interest in microwave beam weapons. They drew up a relatively small scale experimental plan (to be described in detail later). However, the experimental scale right along was not expanded. This is because microwave energies are very difficult to direct. Moreover, compared to lasers or particle beams, they are easier for the enemy to defend against. They require making high power microwaves converge on targets at fixed distances and need huge antennas.

However, a recent Pentagon announcement made clear that a certain type of specially fixed radio frequency could be used in order to destroy military communications facilities, aircraft, and missiles. At the same time, it is also thought possible to use them in order to destroy people. This type of weapon has a possibility of becoming reality some day soon.
Reports say that normal radio waves have no effect on people /40
or precision high technology systems dependent on computers. However, U.S. scientists specially engaged in radio wave weapon research say that certain frequencies are capable of being used in order to destroy computer integrated circuit modules. Within half a second, it is possible to take expensive weapon equipment and turn it into a pile of scrap iron. What is worth paying attention to is that a number of key U.S. weapons-- for example, the F-16 fighter, the M-1 tank, precision guided conventional missiles, nuclear warhead missiles, as well as many military communications facilities (including radar stations and satellites) all are equiped with computer integrated circuit modules.

The reports in question say that Soviet radio frequency technology has already developed to a stage adequate to make short range radio frequency weapon prototypes. This could lead the U.S.

Scientific research clearly shows that very low frequency electromagnetic beams damage cerebral function capabilities. U.S. scientists say that strong microwave frequencies are capable of causing soldier panic, even leading to death.

2-13 Competition Surrounding Lasers

The production of laser technology can be traced back to a prophecy made by Einstein in 1916: There is no need for outside effects. Atoms and molecules are then capable of emitting or absorbing photons spontaneously. This point was clear at that time. At the same time, Einstein also put forward another type of possibility. When a certain wave length of light impacts atoms and molecules, those atoms and molecules are then able to be excited and emit photons of the same wave length. This phenomenon is called stimulated emission. In 1928, Ladengboge (phonetic) proved that Einstein's prophecy is correct. At that time, due to the fact that stimulated radiation was drowned by spontaneous radiation, as a result, it appeared difficult to detect. However, physicists long before already knew how to set up appropriate conditions to make stimulated radiation achieve practical applications.

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The first person to put stimulated radiation to practical use was the Columbia University physicist, Julius Turner. In 1951, he was in the midst of efforts to find a type of microwave producing system with outstanding properties. One clear early spring morning, before going out to participate in a symposium in the area of physics, he sat on a Washington park bench. At this instant, in his brain, was born an idea for how to apply stimulated emissions. At that time, he did not dare to confirm whether or not this idea was workable. However, he felt there was a need to make one of his graduate students, Thomas Gordon, go and try it out. Two years later, Turner, Gordon, and Herbert Qige (phonetic) made the first "maser" (a short term for stimulated emission radiation microwave amplification).

A few years later, people tried to take "maser" operating methods and expand them to even shorter wavelength light waves. In the later 1950's, Turner and Yase Xiaoluo (phonetic) published a book on laser theory. At that time, they called it an optical "maser". Analogous work was also under way then by Nicholas Basuofu (phonetic) and Alexander Puluohuoluofu (phonetic) of the Moscow University Liebiejiefu (phonetic) physics institute. Later, these four men all won the Nobel Prize: The three men-- Turner, Basuofu (phonetic) and Puluohuoluofu (phonetic)--due to research work in the areas of lasers and "masers", divided the 1964 Nobel prize for physics. Xiaoluo (phonetic) took a 1981 (illegible) Nobel prize for work in utilizing laser spectra to study the interior structure of atoms. Competition in scientific research finally led to the birth of the first laser.

At that time, most researchers belived that lasers were only a type of very low power system, very like its relative--the microwave generating "maser". However, there was one person-- Gedeng Guerde (phonetic)--a graduate student in the Columbia University physics department, who still did not believe this. He did not work directly for Turner. He said his work and Turner's work were mutually independent. Guerde put forward his own optical maser concept. In conjunction with this, he wrote down notes relating to this concept. In these, he took radiation given rise to by stimulation, amplified their effects, and refered to it by the acronym (LASER). Guerde (phonetic)
wholeheartedly believed that he had become an inventor. /42
Because of this, he did not, as people had normally done, take his results and publish them in scholarly magagzines. By contrast, he applied for a patent. Due to troubles with examiners, Guerde (phonetic) lost all in a series of patent applications. However, the term "LASER", which he invented,

replaced the overelaborate "OPTICAL MASER". He did not give up. After going through many years of suits, Guerde finally got two patents. One was in 1977. The other was in 1979.

Guerde (phonetic) left Columbia Unversity, taking his ideas relating to high power lasers to the TRG Company. This is a small company located on Long Island, NY. They took his ideas as the foundation for drawing up a research proposal to present to the Dept. of Defense, requesting 300,000 U.S. dollars for preparatory research expenses. The DoD high level research planning bureau was very interested. In 1959, it gave this company an appropriation of one million U.S.dollars.

Guerde (phonetic), Xiaoluo (phonetic), and Turner, as well as most of the participatants in the laser competition were trying to make gas lasers. Their objective was to take energy (illegible) in gases, and, following that, get laser beam output. This process later required detailed (illegible). Theoretically speaking, using gas media to produce lasers is the optimum choice. Indeed, there are already many models of gas lasers in broad applications.

Besides this, certain solid materials are also capable of being used in order to produce lasers. This fact was first recognized by the winner of this laser competition--Xiaoduo Mamen (phonetic). He worked at the Hughes research laboratory in Malibu, California. He used a synthetic ruby rod to make the first solid laser. A number of physicists had catagorically asserted that this type of material could not act as a laser operating medium. Mamen (phonetic), at that time, was in the midst of studying ruby optical properties. However, he did not have blind faith in the inferences of other people. He made this kind of experiment: he placed a number of mirrors around the

circumference of a ruby rod, causing the ruby rod to be placed in the middle of spiral shaped flashing light. He paid attention to the flashing light's strong light energy being able to stimulate ruby emission of red light pulses. When the DoD high level
research planning bureau (this is an agency set up under the Pentagon specializing in leading and coordinating research projects which are risky but have a future) was in the midst of giving the TRG Company an appropriation of one million U.S. dollars, Mamen (phonetic) still--without government support--fought on alone. Guerde (phonetic) said that, in fact, the Hughes research institute had certainly not let Mamen (phonetic) do work in the area of lasers. However, he did it, and, in conjunction with that, on 7 July 1960, announced the birth of the world's first solid laser (see Fig.2-5). /43

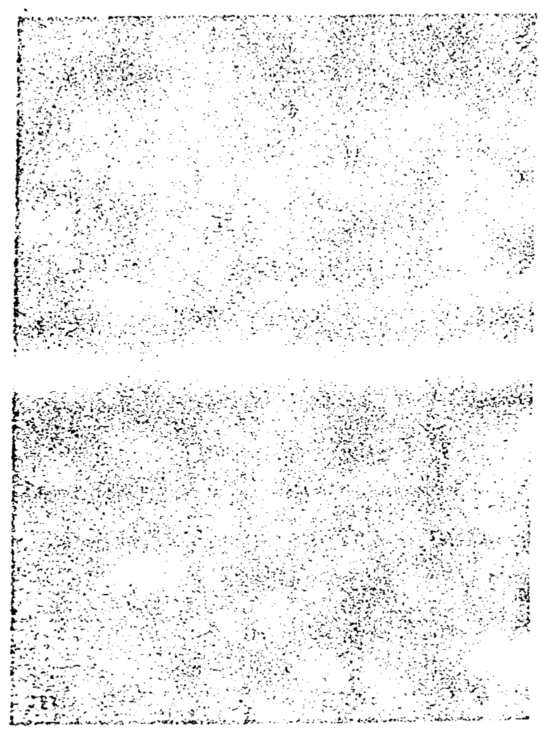

Fig.2-5 The First Ruby Laser Made by the Hughes Laboratory in Malibu California by the Scientist Mamen (phonetic). In the Fig., the spiral tube produces strong pulses of stimulated light. It is capable of stimulating the artificial ruby to make it emit pulses of laser light.

In the several months after that, reports of other models of related lasers appeared one after the other. This was foreshadowing--due to the broad

potential applications of lasers- -that it would lead to big breakthroughs in technology.

The researchers in this field were puzzled by laser power outputs being this small. The continuous power output is normally only on the order of watts. In order to increase power, researchers were normally compeled to drew help from means of amplifying laser light. In the early 1960's, the carbon dioxide laser had the strongest power. The wavelength was 10 microns.
It was located in the infrared region and was a type of /44
nonvisible light. It was made by Potter of the Bell laboratories. Increasing the length of carbon dioxide lasers would not necessarily be effective. The reason was that, before output powers reached practically significant levels, lasers would show the appearance of strange properties. The theoretical limits were: carbon dioxide lasers are capable of continuously outputing powers of 8800 watts. This type of laser device has a length of 230 meters. Some people joked (illegible): "If lasers can only be militarily significant when they are this huge, there is no need to operate them. Just use them to smash the enemy to death!".

Early lasers were not capable of acting as weapons. However, they could still act as supplementary aids for weapons as the Pentagon quickly discovered. Ruby lasers and analogous lasers of different types (operating media are other types of composite crystals, containing inside small amounts of rare earth element neodymium) are capable of aiding soldiers in aiming at targets. One type of system among these is called a rangefinder. It is only necessary to measure the time spent by the laser pulse going from the soldier to the target and back to then be able to know how far away the target, thus guiding the execution of small arm

and missile attacks. Another system is called a target indicator. It is capable of taking targets and turning them into a series of encoded laser pulses--for example, conventional bombs equiped with homing systems or missiles capable of flying toward targets in accordance with faculae light striations shown by target indicators.

During the Vietnam War, the U.S. made the first use of this type of weapon in "smart bombs" using lasers to indicate targets.

At the end of 1970, Qiaozhi Gemota (phonetic) declared that laser rangefinders and aiming devices are the most successful investments of the past 10 years.

2-14 Achieving High Powers

Around 1970, laser technology showed the appearance of /44
several breakthroughs. This restimulated Pentagon interest in high energy weapons. This type of breakthrough was concentrated in two types of lasers: carbon dioxide lasers and chemical lasers.

After Potter built a carbon dioxide laser, people very rapidly realized the potential of its high output powers. However, due to a series of problems still not being resolved, at that time, it was also not possible to take this type of potential and turn it into reality. This type of situation went on right up until the year 1967 and was only concluded after the building of carbon dioxide lasers associated with relevant gas kinetics. Speaking from statements by Pentagon officials, gas kinetic carbon dioxide lasers were the first gas lasers to reach high powers. Its development as a laser weapons system paved the way. At that time, there was a report that revealed the Pentagon

covered it with a veil of secrecy. The report said that continuous output powers had already reached 60 thousand watts. At the same time as this, a small Soviet team also did similar work. This is perhaps the reason why U.S. researchers felt that it was not necessary to maintain secrecy about this as they had before.

In the 1970's, chemical lasers also made important progress. The energy of chemical lasers is supplied by chemical reactions. Their basic idea is similar to the carbon dioxide laser. It can be traced back to the early 1960's. However, it was not until 1969--due to series of technological advances--that the feasibility of realizing high power outputs was definitely shown. More advanced research work made chemical laser output powers reach new heights. At the same time as this, powers associated with carbon dioxide lasers also reached a new level (see Fig.2-6 (A) and (B).)

It was not long until the Pentagon carried out experimental verifications of the feasibility of lasers acting as weapons. To this end, the Air Force built gas kinetics carbon dioxide lasers. U.S. officials asserted that this is a type of medium power laser. Moreover, nonofficial news said that it was capable of producing several hundred thousand watts of power. In early 1970, under highly classified conditions, the lasers in question were used for experiments at Kirtland Air Force Base, New Mexico (the Air Force weapons test base). According to the statements of on site observers, when the laser beam was fired toward the target, it was burned. In 1973, at the Kirtland Sangdiya (phonetic) optics experimentation center, ground based lasers went through the shooting down of flying targets, making fuel catch fire and cutting control circuits. The detailed status of the experiments was secret right through

up to 1982. It was only at laser and elecrooptics annual conferences that participants were lucky enough to see video recording the contents of this experiment.

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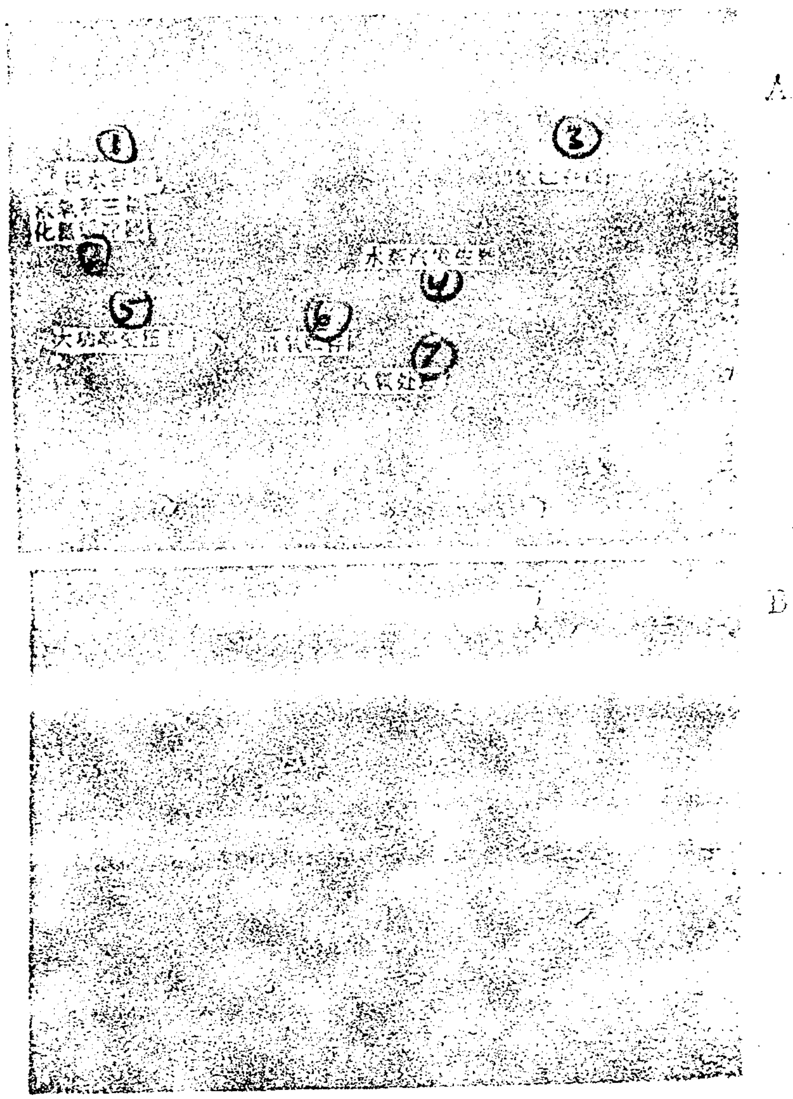

Fig.2-6 Rocketdyne High Level Chemical Laser Schematic. It was built by the Rocketdyne subsidiary of the Rockwell International Company. The first demonstration tests were made in 1977. Its lasers are capable of producing powers of 100 thousand watts. In each iteration, sustainment periods reached 200 seconds. Fig.(A) is the laser laboratory and various types of gas containers filled with materials such as hydrogen, (illegible), gaseous and liquid (illegible), heavy hydrogen (deuterium), (illegible) and so on. Fig.(B) is a laser diagram. This equipment was installed at a location in the center in Fig.(A). The U.S. Defense Dept. has already used this laser to go through various types of weapons tests. (1) Water Supply Container (2) Liquid Oxygen and (illegible) Buffer (3) (Illegible) Storage Container (4) Water Vapor Generator (5) High Power Transformer (6) Liquid Oxygen Storage Container (7) Liquid Oxygen Handling

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Soon afterwards, the U.S. Army also used lasers to carry out tests. They hardened a laser of 30-40 thousand watt power on a combat vehicle the size of a tank. At Alabama's Redstone Arsenal, use was made of a type of "mobile experimental vehicle" to hit flying targets and helicopters. What was interesting was that it was certainly not this test but tests slightly later that made army officials believe that, on the ground battlefield, lasers could be very useful. Lasers were also moved out of tanks to become the Army's first laser weapon. Later, they were also given to the U.S. NASA's Marshall Spaceflight Center at Huntsville, Alabama and were used in order to research rocket propulsion technology.

In March of 1978, the Navy also made related tests. They used a medium power chemical laser (the reported power was 400 thousand watts) to destroy a TOW type antitank missile. The test was carried out at California's San Juan Capistrano. This is one part of the Navy's whole field experimentation program.

In the 1970's, military research projects were far from stopping with these. They expanded into a number of other fields--for example, basic laser physics, optical components needed in high energy lasers, beam--target mutual effects, aiming and tracking, as well as transmission of laser beams in the atmosphere, and so on. At the end of fiscal 1978, Pentagon expenditures on laser weapons had already exceeded one billion U.S. dollars. After that, expenditures continuously increased. At the end of fiscal 1982, expenditures were approximately two billion U.S. dollars. Even by Pentagon standards, this type of expenditure on one research project is unusually huge.

Weapons specialists have had a number of doctrines. Before, people used gas kinetic lasers right along to carry out laser effects tests. In the 1970's, they discovered several big problems in the area of gas kinetic lasers. During tests conducted in airborne laser laboratories, what the Air Force used was 400 thousand watt gas kinetic lasers. However, this type of laser beam is not capable of penetrating air very well. From the angle of practical use, it is possible to make use of what one specialist said. Gas kinetic lasers are a "ten ton wrist watch". Despite the fact that the components they use are all very precise, they are still, however, an enormous piece of equipment with very indifferent results.

This type of awkward situation for researchers was also produced: in February 1981--taking too much on their own responsibility--Air Force officials announced to a news conference that they would use airborne laser laboratories to destroy AIM-92 "Crosswind" air to air missiles. The experiments were carried out at California's China Lake Naval Weapons Test Center. However, the missiles were not hit. Soon afterwards, the newspapers carried articles saying, "laser weapons did not pass the test". Hard pressed Air Force officials still adamantly said the tests were not a failure--that they learned a lot from them. Until 1983, they did not again make public announcements before airborne laser laboratories shot down "Crosswind type" missiles.

The status of Soviet laser weapon development has been very secret all along. Pentagon officials estimate that, in this area, the Soviet effort is 3-5 times that of the U.S. It was just at the time that the U.S. made a big increase in the budget for laser research that the Soviet Union also went into action in accordance with original plans. As far as the status of related weapons research is concerned,

there was also coverage in openly published Soviet science magazines. However, the proportions accounted for by them was larger than the ratios accounted for in similar magazines in the West. Even so, this certainly does not make clear the scope of Soviet research for sure because publishing policies in the East and West are different.

During the few years past, interest by U.S. military circles in laser weapons associated with nuclear missile defense has clearly increased. This idea's original supporter is Senator Maer(illegible)mu Waluopu (phonetic). In the laser weapons budget--in particular, the budget associated with the area of space based weapons systems--there are clear signs of this. Currently, several types of ideas for new model laser weapons have also appeared. These are none other than free electron lasers, X ray lasers, as well as þ ray lasers. These will be described in detail a little later.

2-15 Particle Beam Weapons

With regard to particle beam technology, it is possible to trace it back to the early period of subatomic physics. At that time, physicists set up the first atom smashing devices. The specific idea is to take subatomic particles--electrons, protons, ions--and put them through appropriate arrangements of electromagnetic fields in order to accelerate them to very high speeds. Once particles have accelerated to very high velocities, they are then capable of being used in order to probe the interior structure of the atom.

The first particle accelerator was built approximately a half century ago. During the Second World War, the U.S.

Defense Department had already begun considering the feasibility of using it to make weapons. At that time, military officials asserted categorically that the technology was still not mature. About a year after that, technology achieved great advances. In 1958, the U.S. Defense high level research planning bureau believed that the time was ripe. In conjunction with this, at Laurence Livermore laboratories, execution was begun on a project codenamed "Xisuo (phonetic)" (see Fig.2-7). Its purpose was to use electron beam weapons to act as ground based defense systems for strategic areas in order to defend against ballistic missile attacks. Before stopping the "Xisuo (phonetic)" project in 1972, 27 million U.S. dollars had already been spent. The reasons for stopping this project--according to the Pentagon were: "The expenses in building this type of system are too great. Moreover, it is very difficult to solve transmission problems when beams penetrate air." The (illegible) difficulties lie in the fact that it is not easy to find a type of method to make electron beams penetrate atmospheric layers along a predetermined path in order to hit targets. Lightning is the best example. Its track is difficult to predict.

The conclusion military experts drew from the "Xisuo (phonetic)" project is: from now on, particle beam weapons must be researched carefully (that is, with proper limits and direction). In 1974, the Navy began a project codenamed "Enjoy the Inheritance at Leisure (Zuo Xiang Yi Chan)". In this project, electron beams were also used. Here, electron beams were used in order to protect warships, causing them to avoid the attacks of aircraft and missiles. It acts as a "point defense" system. Moreover, that it is not a large area defense system has desirable aspects. According to military planners, Navy requests are relatively realistic. The reason is: beam ranges do not need to be too far. In

this way, a series of problems such as beam direction are simplified. Another reason is: targets are normally very close to electron beam emission systems. In this way, systems can be made relatively small. Manufacturing costs can then be relatively low. Because of this, the "Enjoy the /4 Inheritance at Leisure (Zuo Xiang Yi Chan)" project is certainly not one that spends a lot of money. In the period 1974-1978, it only required 21 million dollars from the Department of Defense. Compared to the several hundred million U.S dollars spent in the area of laser weapons, this is indeed a small amount. In 1977, Congress took "Enjoy the Inheritance at Leisure" and shifted it from weapons development projects to basic research. The reason was that it did not have much possibility of development as a weapons system in the near future.

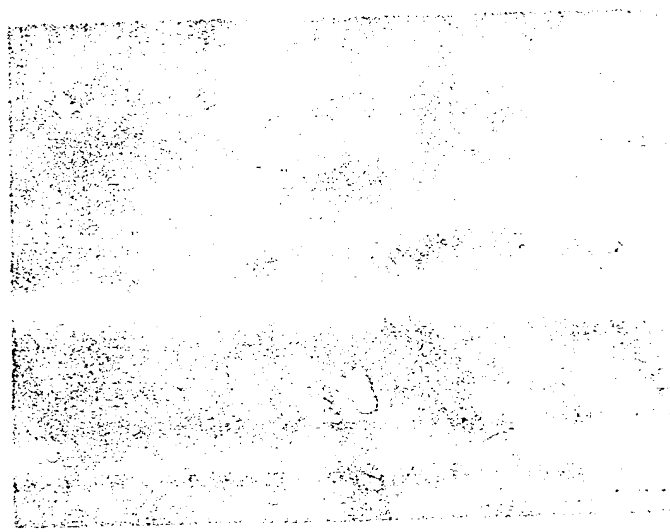

Fig.2-7 Interior View of the Pentagon's Largest Particle Accelerator Laboratory Used to Provide Experimentation for Weapons. (Illegible) High Level Experimental Accelerator at California's Laurence Livermore (illegible) Laboratory. Two operating personnel are in the area (illegible) lighted at the upper right.

It goes without saying that, whether it is the "Xisuo (phonetic)" or "Enjoy the Inheritance at Leisure (Zuo Xiang Yi Chan) projects, they are both reckoned as small scale projects. This is due to their being strongly dependent on large model accelerators. The first is the Atomic Energy Commission. After that, is the power source research and development office and the Energy Department. They have all spent several tens of millions of U.S. dollars to build different model particle accelerators used in research in subatomic physics and other fields. Large scale accelerators are under construction at such places as (illegible) national laboratory (illegible) national laboratory. This technology is not capable of direct use in directed energy weapons systems. The reason is that directed energy weapons need strong beams to destroy targets. However, accelerators used for research are only capable of producing very weak beams. Even so, accelerator technology development is capable of laying the technological foundation for military applications.

In the 1970's, the golden era in particle physics development already ended. Speaking more precisely, the money was all spent. At that time, physicists requested the U.S. Government to support the construction of larger, better accelerators. However, official replies disappointed them. The reasons were that the money required was too much, and the experimental results obtained were also too difficult to predict. It was hard to convince the money people. In this type of situation, the original people really felt at the end of their rope with regard to the development of accelerator technology for pure research purposes. It was not long until their thoughts turned to applications of accelerator technology in other fields. Besides acting as weapons, particle beams were also very useful in fusion research--in particular, in the area of

inertial binding nuclear fusion studies. The principle is that, on micro fusion material targets, making use of an unusually short energy pulse, (illegible) target produces collapse and explosion. The explosion produces high temperatures and high densities--for unusually short sustainment periods--as required by fusion reactions. Moreover, plasma bodies are inertia bound. It gets the name for that reason. Once lasers began to be used as a means, there was later a gradual expansion to proton beams and other ion beams.

Despite the fact that research associated with the magnetic binding type of fusion seems to pertain to peaceful utilization projects. Inertial binding, however, has a military aim. Micro explosions of fusion fuel are small scale hydrogen bomb explosions. As a result, inertia binding fusion energy simulates the effects of nuclear explosions. In view of this, certain experimental results are classified. The plan as a whole is carried out by the U.S. Energy Department's military projects office. This is an organization responsible for research in development of nuclear weapons.

Pulse power technology is one part of accelerator technology. Pulse power includes ultra high voltage production, switching, and the production of such things as subatomic particles or particle beams.

The Soviet Union looks very seriously on research associated with pulse power technology. In 1978, a report coming from the Rand Corporation said, beginning in the middle 1960's, the Soviet Union had already made very great efforts in this field. The conclusions reached by the report said: the Soviet Union is in the midst of taking key energies and using them in the area of pulse power. The basic subjects

in this area are: (1) controled thermonuclear fusion acting as a national energy source; (2) military applications.

As far as Soviet interest in applications of particle beams in military areas is concerned, the initial disclosure was by U.S. Air Force General George Jigan (phonetic) a year before he retired. Not long after he retired--in January 1977--he filled a vacancy as chief of Air Force intelligence. In the National Security Council, he put out to the news media a simple report. He warned that the Soviet Union had been very effective already in researching particle beam weapons used in the area of ballistic missile defense. Due to the fact that he felt that his intelligence analysis had not been able to convince top level people at the Pentagon, as a result, he decided to go public with his analysis. When he talked with "Science" magazine reporters, he said that his aim was to warn, and, in conjunction with that, to give rise to a sense of concern about the situation.

Not long after, "Aviation Week and Space Technology" magazine published an article based on Jigan's (phonetic) talk. The article publicly condemned the Soviet Union as being in the midst of building particle beam weapons used to destroy U.S. ICBM's and ballistic missiles launched from under water. This magazine's military editor, Kelalunsi Lubinxun (phonetic) supplied evidence that the Soviet Union was carrying out this plan. In conjunction with that, he added that, due to controversies within U.S. intelligence departments, the actual status of Soviet development of directed energy weapons had still not been submitted to the President or the National Security Council.

For a long time, this magazine has been a consistent advocate of radical military view points. Due to its always being eager to disclose a number of classified materials, among Air Force organizations, it is sometimes called "Aviation Leak" (in English "Aviation Leak" and "Aviation Weak" are homonyms). The circulation reaches 140,000, and magazines with large readerships influence the military and Congress. However, people still have this sort of impression--even if this magazine publishes news, it is certainly not completely reliable. For example, in 1958, "Aviation Week" published this report: the Soviet Union is carrying out flight tests of nuclear powered /49 bombers. At that time, the U.S. was also planning to build one. However, it met with opposition in Congress. In 1961, the U.S. plan was still finally (illegible) dropped. After that, reports relating to Soviet nuclear bombers never appeared again. In fact, there was no evidence of any kind to clearly show that the Soviet Union was in the process of building this type of aircraft either. Finally, (illegible)ci (phonetic) said that the news in question was supplied by a government official. He said in this way that it was right. What is not clear--or will perhaps ever be clear--is whether this instance of leaked secrets was a calculated lie or an intelligence mistake. Later, the magazine in question tried hard to make people forget their mistake and made a good number of efforts. For example, at the end of 197(illegible), there was this type of mistaken report--obviously an intelligence agency mistake--that U.S. spy satellites had been "blinded" due to Soviet laser beam attacks. Military analysts only knew later that that was a natural gas fire within the Soviet Union and not a laser launch. The paper reporting this attack incident summarized laser weapon technology. However, in the end, it was not quoted by "Aviation Week".

No matter what one says, the magazine run by Lubinxun (phonetic) really stirred up a hornet's nest, with a large number of troubles following on its heels. Scientists carried on disputes about test results. A good number of people even expressed doubts about the feasibility of the entire hypothesis. Congress began carrying out investigations. The DoD high level research planning bureau commissioned the Rand Corporation to carry out studies. A Swedish scientist's report said that, in the atmosphere, soundings had found radioactive isotopes with short lives. He believed that it was possible the Soviet Union had carried out particle beam tests. Other people expressed doubts about his explanation. Later, he was notified that his observation results and the results associated with "Aviation Week" reports were not consistent.

In fact, the status on the Soviet side is a puzzle all along. In recently written Pentagon situation briefings relating to the status of particle beam research, it said, "Soviet efforts in the area of particle beam research will be much greater than the U.S. This is particularly true in the area of applying accelerators to fusion. It is estimated that they have already made long strides in development. However, open source reports on work by the Soviet Union relating to the mutually connected particle beams and weapons have not been seen." Even so, observers in the Pentagon and outside it do not doubt for a minute that the Soviet Union carries out particle beam research.

Due to impetus from the U.S. Congress, the U.S. Defense Department finally began to increase expenditure outlays for particle beam weapon research. In fiscal 1979, the "Enjoy the Inheritance at Leisure" project was taken over by the national defense high level research planning bureau. The research expenditures increased year by year. From the 18

million U.S. dollars used in all military particle beam research in 1979 to 50 million U.S. dollars in 1983. Particle beam weapons and laser technology alike both belong to the Pentagon's "directed energy" plan.

At the present time, takes the development of particle beam weapons and places it behind laser weapons. This can be seen through the 1983 financial budget. As far as this fiscal year is concerned, laser weapon appropriations are 8 times more than particle beam weapons. Relevant particle beam technology and the current situation will be introduced by following specialized chapters.

Surrounding the development of beam weapons--in particular, President Reagan's proposal to set up a system to defend against ballistic missile attacks--(illegible) has been unceasing. Reagan's speech relating to setting up ballistic missile defense systems accelerated the appearance of new thinking associated with missile defense system design. In his report, this type of new concept took a prominent role, that is, take strong laser devices and place them on the ground. After that, take the beams and shoot them toward combat reflecting mirrors in orbit and use the reflected beams. In conjunction with that, make them fire toward targets. Another type is nothing else than firing only at the necessary moment at "counter attack" weapons systems in outer space.

During this controversy, Reagan was drawn in (illegible) the pronunciation of his name has a double meaning (in English, Reagan's name and ray gun are homonyms).

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Chapter III MYSTERIES OF BEAM WEAPONS

Over a long period, beam weapons have always carried with them a strange and unreal coloration. They seemed mysterious and unfathomable. People have generated a number of misunderstandings about the power they possess.

For more than 20 years, laser researchers have confronted a series of problems making people confused and perplexed, working mightily. In 1962, in a supplement to a U.S. daily "Sunday", there was published an article called "The Incredible Laser". This article predicted that lasers could become weapons. Not long after this article was published, a copy of it immediately appeared on the office door of Stanford University scientist Yase Xiaoluo (phonetic). On the side, there was the note: "If you want to know the incredible laser, please come in." (see Fig.3- 1). Commercial people making laser systems certainly could not comprehend this type of misunderstanding which people at that time had that all lasers were dangerous. They just hoped for a good laser market.

In reality, many civilian companies had already made a good number of harmless lasers. In "Lasers and Applications Magazine", there were published figures which clearly showed that, in 1982, the volume of business for nonweapon lasers reached 340 million U.S. dollars. Included was a volume of business for laser system equipment which reached 2.6 billion U.S. dollars. Of course, in this, there was a portion which was put to military uses. However, the majority (approximately 2 billion U.S. dollars) was used in nonmilitary ways. Up to the present, the volume of sales in this area is still growing. To sum it up, the main uses for lasers are in the civilian area--for example, medicine,

communications, and other fields. However, the majority of people among the masses still believe that lasers are extremely dangerous "death rays". One should say that, in this field, people doing the work have a responsibility to the public to carry out correct propaganda.

There are people who often blur the difference between science fiction and reality. With regard to this, Wells did a good deal of beneficial work. However, many science fiction novelists still have not conscientiously approached it.

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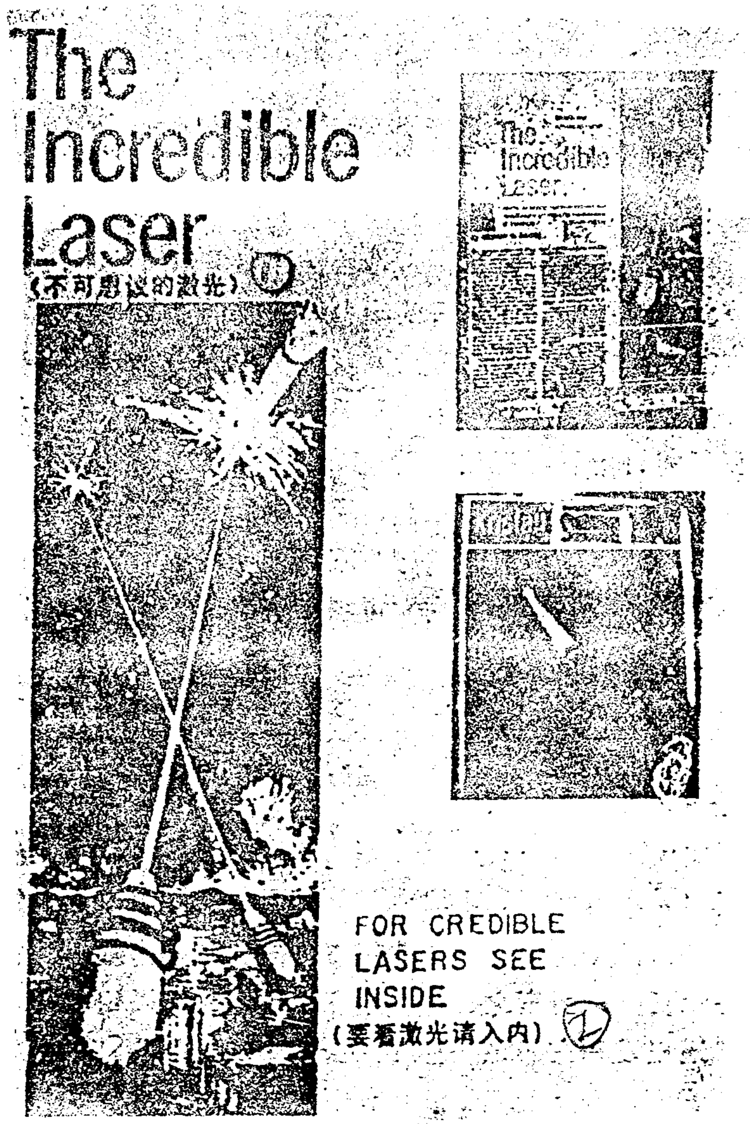

Fig.3-1

Key:
(1) The Incredible Laser (2) Those wishing to see lasers please come in.

The upper right Fig. is a photograph from an article called "The Incredible Laser" published in the supplement "This Week" of a U.S. daily "Sunday" in 1962. This photograph and the headline are juxtaposed at the top. In the Fig., cannon like lasers are in the midst of firing laser beams at missiles. This Fig. made one of the pioneers of laser

research, Yase Xiaoluo (phonetic), very agitated. He took this picture and stuck it up on the door of the Stanford University laser laboratory. In conjunction with this, he (illegible) an artist (illegible) put up the picture on his door in the same way. Above it, he wrote: "After some years, I will (illegible) distribute a postcard with this picture on it to every far away nook and cranny of the world. When the author of this article can also see it, he will marvel that the headline of this piece was chosen as it was, so aptly." However, quite a few laser pioneers had skeptical attitudes toward Xiaoluo (phonetic). They believed that they (illegible) understood the problems there were in laser operations.

Quite a few people still described lasers as lethal weapons. /53
In reality, most science fiction type weapons had no relationship at all to the concepts of weapons that the Pentagon and the Kremlin had tentative plans for.

The majority of science fiction authors all wrote this way. This may possibly be related to the motive for writing science fiction novels. Science fiction stories require futuristic weapons in just the same way as historical novelists have their own creative forms. Plots are all a type of convoluted story. Weapons are traditional, and creative plots are the key props. In most early science fiction works, authors created various types of new model weapons at will, making them possess unlimited power or saying that they were 25th century weapons with six firing apertures. A number of authors strived to make their made up weapons seem real. They either gave weapons a name which seemed real or borrowed the name of a real weapon (for example, laser). However, very few people conscientiously thought through how lasers would play their role as weapons. Perhaps they thought that this was not their task but that of weapons designers. Their job was only to write a story. Due to the fact that beam weapon research is highly

classified, this was also nothing else than an opportunity for the creativity of science fiction writers to supply a number of fantasies and conceptions.

Directed energy weapons are actually capable of playing roles which other weapons cannot. However, they absolutely do not have inexhaustible power. Because quite a few key links associated with directed energy weapons are still far from mature, beam weapon uses are also limited. There are people who believe that, in the foreseeable future, the following types of situations will not appear:

(I) Hand held "ray guns", "destructor beams", and "death rays".

(II) Space based weapons which are capable of destroying ground targets at will.

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(III) "Death stars" capable of making planets explode.

(IV) Beam weapons having huge destructive powers and capable of creating nuclear catastrophe.

3-1 The Ray Gun Myth

Ray guns as props in science fiction works have already been around for a number of years. When children play, they often use their hands to point at each other, shouting, "Your dead!". At this time, they are imagining that they have the power to kill their opponent as they please. Originally, ray guns which appeared in science fiction novels only fired beams and heat flows. Soon afterwards,

there then appeared an "arms race" in science fiction novels of various types of mysterious ray constructions capable of hitting and killing the enemy and produced of printing presses in the popularization period (see Fig.3-2).

Laser beams carry optical energy straight to targets. However, particle beams, by contrast, use fast moving particle forms to carry energy to targets. Strong microwave beams can make targets heat up. To sum it up, the unique way beam weapons destroy targets is to release their energy on them. With regard to casualties, destruction, and instantaneous death, by contrast, they are pure fabrications of science fiction novels.

In reality, the concept of beam weapons being small enough to hold in the hand diverges widely from the real situation. For example, the volume of equipment for generating high power microwaves is unusually large. Even more important is the fact that beam divergence is unusually severe, leading to heating effects not being produced only a few meters away from emitting devices. Speaking in terms of particle generating devices, a compact particle generator can be mounted inside the outer shell of a dump truck. However, it needs a high power electric source to support its use. There are several units of gigantic particle beam generating equipment in the world. One among them is the two mile long Stanford linear accelerator system.

Lasers can be made very small. However, the smaller their volume is, the smaller the power produced also is. Certain amateurs built what looked to be a laser handgun of lethal power. However, in reality, it was only capable of injuring the eyes. This form of danger was similar to the harm produced to the eyes by the sun. In the U.S., use of this type of device at a public occasion is illegal. The most

severe laser harm to the public/55 certainly is not posed by toy models. As far as models of lasers sold in the marketplace are concerned, not one possesses this kind of capability. Perhaps the lighting of rock bands could more easily wound people. They take colored light columns and sweep the audience. This will produce damage to the eyes.

Fig.3-2 The toy ray gun, in reality, is a spray device. Real hand held type lasers resemble the kind shown in the bottom Fig. Its energy is supplied by a 1 (illegible) 2 volt storage battery. According to the New Hampshire, Amherst information company manager, Yinaini (phonetic unclear), ruby lasers are capable of being used to drill holes. However, in reality, they are only capable of going through thin material or producing damage in peoples' eyes. They have no capability against helmets and body armor or armored tank plates. (see page 91-A)

Powers of hand held lasers are very low. They cannot kill any organism larger than a fly. It is said that several /56 engineers used laboratory lasers as "flyswatters". Making a laser of very great power carry out attacks on certain large targets is completely possible. However, its volume is very large and not easily portable. The reasons are: (1) Light beams certainly are not the best way to cause injury to bodies. (2) Transfer efficiencies associated with laser energies themselves are very low.

Injuries caused by bullets and injuries caused by lasers are different. Energies carried by bullets, when they hit the human body, will penetrate the body. Casualty effects of bullets are completed through the creation of mechanical damage--for example, they cause important organs of the body to be injured. Lasers, by contrast, are not this way. The

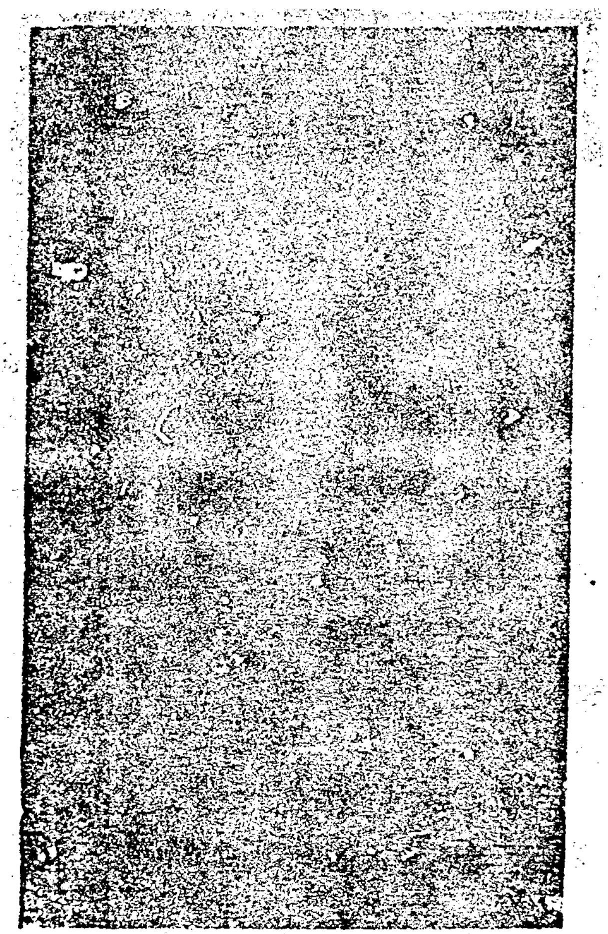

Fig. 3-2

injuries they cause come from taking energy in the form of heat and pouring it into the target. In order to injure or kill the human body, laser beams must have sufficient energy to burn a hole in the body or injure key organs such as the heart. This then requires laser energies much higher than the 300 Joules produced by rifle bullets.

There are people who have calculated the energy required to burn a hole in the human body 1 cm in diameter and approximately 20 cm long. The value is quite large. The hole aperture must be sufficiently large to avoid matter produced by laser evaporation of muscle tissue blocking the laser beam following after. The effect of this type of wound self-closure is very useful in surgical operations. It is able to prevent blood flow from being excessively great. However, when considered in a weapon role, one would still hope it were not so. Producing this type of hole requires energy capable of evaporating 20ml of fluid. This value is approximately 50000 Joules--one hundred times higher than the energy of rifle bullets. In reality, to produce this kind of hole, the energy required is far higher than the value described above. Because--in this process--energies are not capable of being 100% utilized, part of the energy will be absorbed to evaporate body tissue, and part of the energy will be used in order to heat body tissue beyond the evaporation level. There is also a part of the energy which will be reflected or lost in other forms.

Lasers capable of producing 50000 Joule pulses are quite enormous--basically incapable of being held in the hand. In order to avoid heating in operating processes, the matter producing the laser beam must be a gas. Energies which can be obtained from within gases have a complicated relationship of dependency on gas pressures, volumes, and temperatures. If it is required that lasers be small enough

to hold in the hand, /57 the key factor is volume. Any practical laser "small arm" will certainly need to have more than one liter of gas. However, current technology still cannot reach 1000 Joule/liter efficiencies.

The problems certainly have not been resolved. There is also a more complicated problem requiring solution. This is nothing else than that laser transfer efficiencies are very low. Energy used to excite lasers will certainly not all change into light energy. Even under the best of circumstances, energies imputed into gas operating media by electrical discharge or chemical reaction will also only have 20% conversion into laser beam energy. However, the rest of the energy, by contrast, turns into heat and is dissipated. The dissipated energy is 4 times the energy released as laser. On this basis, it is possible to deduce that hand held type laser weapons will become unusually (illegible) hands. In order to get to experimental laser weapons, people will certainly have to wear asbestos gloves. Only then will it be possible.

Due to the fact that, when lasers are produced, energy transfer efficiencies are not high, energy storage equipment then needs to be unusually huge or it will not work. Certain lasers utilize chemical reactions to obtain energy. The energy source is in the "storage container" of the fuel. A number of different laser devices, by contrast, require having huge electrical power sources (see Fig.3-3). Ten or fifteen years ago, in a magazine relating to commerce, there was this type of cartoon published: a scientist was holding a small laser pistol. However, it still had a thick electric cable connected to a huge electric power source behind it.

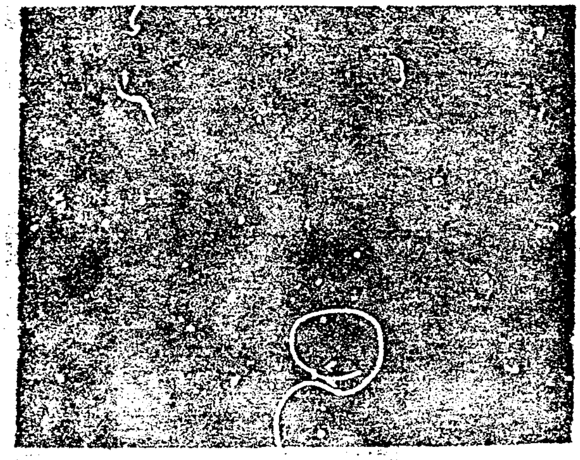

Fig.3-3 Even in lasers the size of tanks, there is still the problem of energy supply. A Soviet laser weapon schematic (illegible) the Pentagon clearly shows that lasers themselves (left) require independent energy supply systems (right). These two parts are connected by a thick power source transmission conduit. It is possible to imagine that energy supply systems will become key targets of attack in combat.

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In the foreseeable future, production breakthroughs in the manufacture of compact, integrated laser weapons are impossible. The difficulty lies in how to overcome heat dissipation problems when volumes are small.

There are people who have roughly calculated, under certain conditions, how much energy can be gotten from one liter of gas. Assuming one has a laser that gets its energy from chemical reactions, the pressures of gases participating in the chemical reactions are 10 atmospheres pressure. Temperatures are approximately ,CVid. When actual chemical lasers operate, gas pressures are certainly not high. Along with that, pressures increase. Numerical densities of atoms or molecules go up. Our use of slightly higher pressures give a somewhat optimistic estimate. Making yet another assumption, beam wave lengths put out by lasers lie in the invisible ultraviolet range (wave length 0.3 microns). In this wave length range, lasers are capable--in the atmosphere--of very good transmission. If every atom or molecule in laser operating gases--in one pulse--can each send out one wave length of photon at 0.3 microns---(this is

one type of excessively optimistic estimate)---then, this pulse will contain 50 thousand Joules of energy. This is the lowest value of energy required to burn a hole in the human body, as was calculated earlier. In rough terms, laser pistols seem to be feasible. However, this simple calculation did not consider a number of other factors. Comparing calculations with actual values, disparities are very large. Although it is not possible to confirm that laser pistols cannot be built, it would be extremely difficult, however.

Theoretically considered, it is most certainly possible to get a very high energy from a very small X ray laser. What must be pointed out is that, although X ray laser photon energies are very high, they still, however, have difficulty in penetrating the atmosphere. The biggest problem is: X ray laser excitation energy threshold values are unusually high. If one wants to put them in operation, it is necessary to have a small nuclear explosion. Of course, this is not what people imagined as that type of weapon which can be carried in a coat pocket.

Due to the fact that people's eyes are extraordinarily sensitive to light, as a result, there are people who think that it is possible to build a type of hand held laser pistol to use in order to injure the eyes. Indeed, when training soldiers to use low power laser range finders, eye safety must receive /59 unusual attention. Below, we will talk about using lasers by certain methods to temporarily or permanently blind the eyes of soldiers.

As far as using powerful lasers to kill and wound soldiers is concerned, is it not just like what was described in Well's book "War of the Worlds"--Martians using heat ray weapons to kill people? Speaking from theory, this is

possible. Actually, it is still not workable. Since there are a number individual soldier weapons associated with cheap investments, high performance military rifles are much cheaper than laser weapons, and they are capable of effective use in order to kill and wound enemy. What attracts people about lasers is that beams propagate in straight lines. On the battlefield, the primary mission associated with the use of lasers is hitting such targets as fast flying missiles, aircraft, and so on. It is very difficult for conventional weapons to fulfil this mission.

3-2 Attacking Ground Targets from the Air

Looking from the angle of laser combat stations in outer space orbit, any person or thing on the ground is an easy target. Mankind's life within the atmosphere is fortunate. The atmosphere is not only capable of causing us to avoid injury associated with harmful radiation from the sun, it is also capable of effectively blocking laser penetration.

It is normally believed that air is completely transparent. However, even visible light will be absorbed and refracted by air. This type of effect makes laser propagation in the atmosphere become very difficult. The physical processes in question are very complicated. The conclusion is still very simple: when lasers reach the target, they already do not possess the energy to destroy it.

Optical engineers and physicists thought up a number of clever methods for reducing the effects of the atmosphere. These methods are effective for short range laser

transmission. However, when satellites fire lasers toward targets on the ground, laser beams will be scattered by the cloud layer and absorbed. This point is very difficult to overcome. At the present time, a good solution has still not been found in order to resolve this problem.

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Still, there are a number of other ideas: space based lasers can produce sufficiently strong laser beams to make the easily flammable gases around oil depots explode--for example, dealing with refineries, chemical plants, and so on. However, it is very difficult to confirm the value of doing this. The reason is that installing a protective umbrella of aluminum structure to defend against laser attacks is much easier than defending against the attacks of a shock brigade equipped with antitank rocket launchers. At the same time, it must also be recognized that building a high power laser system costs several billion U.S. dollars. This will be much more wasteful of money than equipping a unit with portable antitank rocket launchers and speedboats.

The atmosphere is capable of effectively blocking the transmission of laser beams associated with certain types of wave lengths. Air is capable of strongly absorbing carbon dioxide chemical lasers, quasimolecular lasers, and X ray lasers. It is precisely due to the effects of air that it was impossible not to reconsider a number of particle beam weapons prepared for installation in outer space.

3-3 Weapons with Huge Casualty Producing Power

People always love to take machines possessing huge destructive power and put them together with advanced

weapons, and so on. This is perhaps a reaction after experiencing the threat of nuclear weapons. Of course, this type of feeling is understandable. Lasers and particle beams take energy and concentrate it in very small areas. In a certain sense, this is certainly not the same as weapons with huge casualty producing power. Real weapons of huge power indiscriminately "make a clean sweep" of a broad area--for example, nuclear weapons, nerve gas, and so on.

If laser beams expand over a very large surface area, their strength will then be reduced to levels that cannot harm people. If a laser beam of 4 megawatts power (this is the power level produced by orbiting stations) spreads out within an area with a diameter of 200m, its final strength will be about the same as the strength of the sun irradiating the ground. The result is that the area in question will only give rise to a change in temperature. It will not produce any harm. X ray lasers have very great casualty producing power against human bodies. However, when they are fired from space through the atmosphere toward the ground, due to atmospheric absorption, they then /61 become lacking in any power.

Microwaves penetrate the atmosphere. However, they also confront the same kinds of problems as lasers. In order to create effective damage, it is necessary to take microwaves and focus them within a very small area. Due to microwave wavelengths being relatively long, a very large antenna is then necessary. Theoretically speaking, a microwave source of 4 megawatts power in a 400km orbit in outer space fired toward the ground would still be capable of concentration into faculae of 2 meter diameter. The power density is 1000 watts/cm2 --adequate to be used to carry out heating. This kind of system will need an orbiting antenna with dimensions as long as 1km. If the orbiting station goes up, the

antennas will follow along with that and must increase in size.

Relatively low power microwave irradiation will then be capable of giving rise to damage in the human body. Long irradiation times are particularly so. Influences of microwaves on health have been a controversial question right along. Their influences in other areas are still not clear. With regard to microwave irradiation, the Soviet Union set stricter safety standards than the U.S. This clearly shows that they believe that this is a very severe type of "environmental pollution". With regard to this, U.S. specialists have still not realized it (or still have not done this). Due to the fact that all effect mechanisms are fuzzy and uncertain, evidence is still not that adequate. As a result, it is very difficult to believe. There are people who will spend several billion U.S. dollars or rubles to build a high power microwave station in space orbit.

There is at least one type of plan for using particle beam generators as weapons with huge casualty producing powers. However, the credibility and military power of this plan are still not clear. According to reports, the thinking of the Soviet Union is: take a particle beam generator installed in space and aimed at the ground, and utilize high power particle beams to produce lethal high energy radiation showers. Following that, these particle beam energies will turn into atomic or molecular energy in the atmosphere, thus making this type of secondary irradiation produce a radiation shower with a cone shaped distribution on the ground.

When the Soviet Union was engaged in arms control talks with the U.S., they brought up this type of possibility. In

conjunction with this, they proposed signing an agreement banning the use of charged or neutral particle beams against "biological targets"--that is, people. This clearly showed that the Soviet Union suspected the U.S. could already have developed this type of weapon. It is also possible that the Soviet Union was deploying a type of smoke screen used in order to cover up their own plan for the development of this type of weapon. Another course of action is to utilize particle beam generators on the battle field in order to produce radiation shower effects. When beams sweep through areas where enemy soldiers are, they will produce secondary radiation, killing and wounding enemy soldiers.

There is no need to doubt that secondary radiation exists. It is widely known that, when cosmic rays penetrate the upper atmosphere, they will produce this type of radiation. What is still not clear is whether or not it (illegible) used as an effective type of weapon. High energy secondary radiation harms soldiers even more severely than lasers. According to estimates, the power density needed to effectively kill or wound the human body is 18000 Joules/meter2 . Once beams are fired into the atmosphere, they dissipate very rapidly. As a result, secondary radiation produced by the original particles form a circular cone shaped distribution. According to calculations, producing a weapon of this type with military value requires producing 10 billion watts of power each hour. Powers associated with short periods will then be even somewhat higher. (Illegible) current technology is far from being able to reach this requirement.

3-4 Giant Stars Destroying Celestial Bodies

At the same time people were carrying on the debate surrounding particle beam weapons, George Lucas' film "Star Wars" was released. On 25 June 1987, it is the 10th anniversary of the first showing of "Star Wars". This science fiction movie cost 22 million U.S. dollars. The box office value has already reached 1.2 billion U.S. dollars. As far as the size of its viewing audience is concerned, in this, it is possible to see a speck. The image of death stars capable of destroying celestial bodies remains in the minds of a good many people. Even people who understand beam weapons very well have also borrowed help from the image of death stars to describe the power of space based beam weapon combat stations.

The power of death stars in science fiction novels is unimaginable--far exceeding the power of beam weapon combat stations people are thinking about. Unusually rough estimates clearly show that if one (illegible) a globe of mass 6x10(illegible) grams, it requires 10(illegible) Joules of energy. (Illegible) lasers people believe that future lasers can produce 1010 watts of power, that is, 1010 Joules/sec. Even if energy is poured in at an unbelievable speed, a laser will still have to spend a period of 3x1012 years in order to make the globe evaporate. This is too much to even contemplate.

3-5 Beam Weapons and Science Fiction

Science fiction novel writers created a good number of myths and fantasies related to beam weapons. However, they should

not be criticized or censured as a result of this. After all, creating science fiction fantasy works is their profession. Even if they are denounced in the future, this can still only be blamed on people who take science fiction novels too seriously.

Science fiction works are still, in certain areas, very prophetic. For example, Well's descriptions of high powered lasers are just such an example. However, science fiction works have also given people a lot of misconceptions. For example, due to the influence of early works, people right along have been expecting the appearance of robots resembling people with whom it is possible to talk. However, the development of technology is still not like this. Actual robots are just automatic machines in industry. This type of automatic machine is far from being that sort of wonder that science fiction writers wrote about. Science fiction certainly has the attractive power to draw people. However, speaking in terms of beam weapons, it certainly has not reliably described the reality in the several chapters that follow.

Chapter IV HIGH POWERED LASER TECHNOLOGY /64

High powered laser technology in the Reagan strategic defense plans possesses important roles. They are one of the most important technologies among directed energy weapons. This type of technology is one of the key products acquired in the process of the development of physics. The appearance of lasers very, very greatly propelled the development of a number of scientific technologies. At the same time, it also caused lasers to achieve broad

applications in a number of such fields as industry, agriculture, satellites, the military, and so on.

Lasers acting as new models of light source possess four clear characteristics: highly monochromatic characteristics, good directional characteristics, high brightness, and good coherence characteristics. Speaking simply, these are nothing else than lasers' wave length distribution range (or frequency) being very narrow, light beam divergence being very small, focusing properties being good, and light strength being high (optical power on a unit area). Due to these strong points, lasers have already become powerful tools in a number of areas of scientific research. They have broad applications not only in physics but in such fields as chemistry, biology, engineering technology, and so on, as well. Applications to military fields are merely one area among them. However, it should be said that military applications have an extremely large promoting effect on the development of laser technology.

Looking back at history, after the appearance of a number of new technologies, one will then have people consider their applications to the military. For example, with the discovery, in 1939, that splitting atomic nuclei is capable of releasing huge energies, it was not ten years until the U.S. dropped an atom bomb on Japan. Priority adoption of advanced technology in military fields is long standing. Military organizations have close relationships with universities, research institutes, and laboratories. This is certainly not inferior to the combining of enterprises, companies, and financial groups with universities and research organizations. Universities receive financial help from the military and work for it. At the same time, /65
universities also achieve development. In a number of countries, this is already a common occurrence.

Despite the fact that, in laser technology, there are still a number of practical problems which have not been resolved, in their development, moreover, there will be new problems continuously appearing. However, due to the fact that they have important applications in military areas, they will get, as a result, military "favor" and "high regard" right through their development process. Moreover, they have already achieved enormous development. Here, we will, first, do some relatively detailed introduction and discussion of the development status of laser technology.

Lasers are nothing else than light which has been amplified by the stimulation of radiation. In English, this is called LASER (Light Amplification by the Stimulated Emission of Radiation) for short. Strictly speaking, this technical term laser describes a physical process. Lasers, then, are equipment utilizing this type of physical process to produce laser light. Early laser devices were very similar to one another. However, in the past twenty years, the development of types of lasers has been very rapid, causing there to be a number of lasers which, at first glance, seem not to have anything in common. A semiconductor chip is capable of being a laser--called a semiconductor laser. These and red color light emitting diodes used as displays in certain calculators are similar in structure. However, when they operate, they will then produce several thousand watts of invisible infrared light. Besides this, a laser can also be a huge monster like a kind of tall building. Inside it there is such equipment as complicated tubing, valves, as well as gas storage (illegible), and so on. This type of laser can take chemical energy and turn it into laser beams reaching powers of several million watts.

In the development of lasers, several of the most basic contents in them are maintained unchanged. No matter

whether light is produced from solid, liquid, or gas, and, no matter whether laser powers are kilowatts or megawatts, in lasers, there is always a certain type of similar process occurring. Understanding how this process operates with regard to familiar high energy lasers is of key importance. To this end, we will go to the interior world of the atom to make a tour.

4-1 Processes of Atomic Luminescence

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Laser physicists, on the basis of a quantum mechanics view point, call laser physics "quantum electronics". This field of study originates in an important change in twentieth century physics. However, understanding this change requires grasping a number of key concepts associated with physics describing the atom and quantum mechanics.

Let us begin understanding this problem with the simplest case--the hydrogen atom. Hydrogen atoms are the simplest atoms. They are composed of one proton and one electron. On the basis of the laws of quantum mechanics, electrons are only capable of moving around nuclei in certain specially designated possible orbits. Each (illegible) corresponds to a fixed amount of energy. That is to say, when each electron occupies an orbit, the energy of this electron corresponds exactly to the energy associated with this orbit. The energy of the orbit closest to the nucleus is lowest. When electrons are raised into orbits relatively farther away from the nucleus, their energy increases.

In order to track these orbits, physicists give each orbit a designated quantum number associated with an integer, marking from the nucleus toward outer layers. Energy differentials associated with adjacent orbits follow along with increases in orbital radii and decrease (see Fig.4-1).

When electrons "transition" from one orbital energy level to another orbital energy level, the energy change is equal to the energy difference associated with the two energy levels. When jumping to an outer layer orbit (that is, a high energy level), it is necessary to add electron energy. When transitioning to an inner layer orbit (that is, a low energy level), electrons lose energy. Normally, electrons go through absorption or radiation of electromagnetic waves in order to increase or lose energy.

The electromagnetic waves which are absorbed or radiated are ultraviolet light, visible light, and infrared light in the majority of cases. Electromagnetic waves are also called electromagnetic radiation. Electromagnetic radiation is called a photon energy group. If electrons transition to lower energy levels, the energy carried by the photons emitted then is the energy differential associated with the two energy levels. When electrons transition to high energy levels, electrons must absorb a photon. The energy of this photon must be large enough to make it capable of raising the total energy of the electron to the energy corresponding to the relatively high energy level. /67

With this emphasized, light and other forms of electromagnetic radiation, in reality, have a dual nature. They are both waves and particles. In most cases, light manifests itself in a wave nature. It is an electromagnetic wave composed of an electric field and a magnetic field simultaneously oscillating in accordance with a fixed frequency. The wave length (the distance between one wave crest and another wave crest) can be measured. In a number of other cases, light also manifests itself as a particle. Because of this, this type of light particle is also called a photon. Photons are nothing else than optical quanta associated with electromagnetic radiation. Despite the fact that, logically, this looks contradictory, this, however, is the way the things in the world exist.

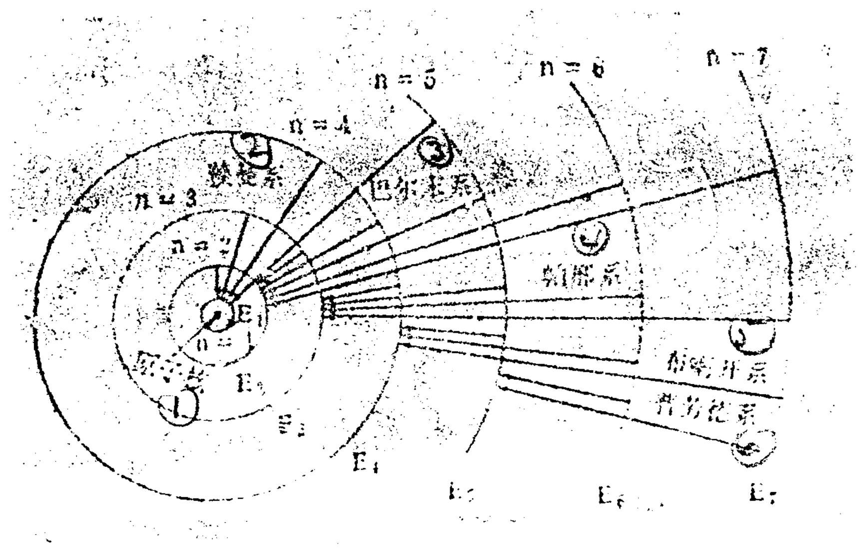

Fig.4-1 Hydrogen Atom Orbital Energy Level Diagram. The farther electron energy level orbits are from the atomic nucleus, the higher the corresponding energies (illegible). If electrons absorb a photon, they will then transition from a relatively low energy level to a relatively high energy level. Conversely, releasing a photon, they will then transition from a relatively high energy level to a relatively low energy level. Transitions only exist when (illegible) energies associated with the absorbed or released photons are equal to the energy differential between the two energy levels. Only then is their occurrence possible. The straight lines between orbits stand for transitions. The people's names above are physicists who recognized that hydrogen atoms use a series of light waves absorbed or released due to transitions.

Key: (1) Atomic Nucleus (2) - (6) Name phonetics illegible.

Electromagnetic radiation is capable of appearing in many forms--radio waves, infrared radiation, visible light, /68 ultraviolet radiation, microwaves, X rays, γ rays are all electromagnetic radiation. There are three basic methods for carrying out classifications of electromagnetic waves: (a) based on electromagnetic oscillation frequency; (b) wave

length; and, (c) photon energy. In reality, these three types of methods measure the same quantity. Only the dimensions are different. Electromagnetic radiation always propagates at the speed of light. The frequency is the quotient of the speed of light divided by the wave length, that is, $\gamma = c/\lambda$. The energy of a single photon is the product of the electromagnetic wave frequency and Planck's constant h, that is, $E = h\ \gamma$. As a result, among the three quantities of frequency, wave length, and energy, it is only necessary to know one of them. The other two can then easily be calculated. From this we know that, when electrons give rise to a certain transition, the light which is emitted or absorbed does not only have a definite energy. It has, moreover, a definite frequency and wave length. For example, physicists are capable of taking transitions associated with wave lengths of 3 microns and saying that they are transitions associated with frequencies of 10 (illegible) H_2 or energies of 0.4 ev (1ev is the energy associated with one electron volt. Its size is the energy obtained when an electron penetrates (illegible) a 1 volt voltage. $1ev = 1.62x10^{-12}$ Joules).

The structure of the hydrogen atom is very simple. As a result, calculating the energies associated with photons put out when electrons transition in their orbital energy levels is quite easy. In complicated atoms with many electrons, atomic nuclei do not have only one proton. They have a number of protons and neutrons linked together. Besides the mutual effects between atomic nuclei and electrons, there are also mutual effects between electron and electron. In this way, it then makes electron orbits and energy levels become quite complicated. Besides this, the nuclei of heavy atoms are relatively complicated. The fine mutual interactions which come from this are capable of leading to energy level fission. There are also a number of other considerations in atomic structure leading to complicated atom orbits being arranged into a series of shell

layers. When there are quite a few electrons in atoms, it is then necessary to consider the Paoli (phonetic) incompatibility principle. This principle points out that, in an energy level, only one electron can exist. To put it simply, the energy level structure of most atoms is quite complicated.

In reality, there is also another level of complexity which must be considered. In the physical world, all atoms are bound together to form molecules, perhaps binding together to form /69 solid or liquid structures. Molecules can vibrate and rotate. Vibrating and rotating energy levels are changed by measurement, precisely resembling the electron energy levels associated with independent atoms. The universal law is that the energy changes caused by electron transition will be bigger than vibration transitions, and the energy transitions given rise to by rotation will be smaller than both of them. Energy distributions in vibrating and rotating modes will also give rise to additional energy levels. When there are vibrations and rotations, it will also produce mutual effects. For example, a molecule producing vibration transitions will often simultaneously change rotational state. With regard to a molecule, it is very easy to produce this type of complicated process. However, speaking for a physicist, tracking this physical process is certainly difficult.

In order to avoid the problem of complexity, sections discussed later on will only talk about normal energy level transitions.

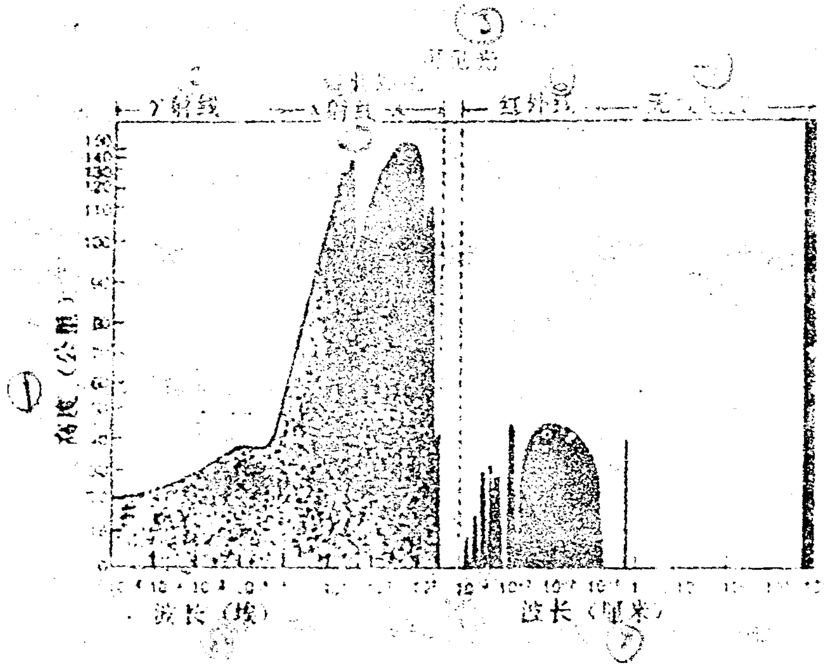

Fig.4-2 Curve Diagram for Various Forms of Electromagnetic Radiation and Atmospheric Thicknesses They Penetrate. The vertical coordinate stands for the thickness of atmosphere penetrated from space by electromagnetic radiation before half is absorbed. The horizontal coordinate stands for wave length (1 centimeter equals 10(illegible) Angstroms). Because the curves in question include (illegible) electromagnetic (illegible), therefore, they can (illegible) indicate a number of atmospheric absorption (illegible) belts. These absorption belts normally lie in the infrared area.

Key: (1) Altitude (km) (2) γ Rays (3) Visible Light
(4) Ultraviolet (5) X rays (6) Infrared (7) Radio Waves
(8) Wave Length (illeg.) (9) Wave Length (cm)

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4-2 Stimulated Radiation

The light put out by such normally seen light sources as light bulbs, the sun, and so on is all spontaneous radiation, that is, in situations where there is no external disturbance, light put out by atoms and molecules transitioning to low energy levels. The process of spontaneous radiation corresponds to electrons automatically transitioning to low energy levels from high energy levels (high energy states or excitation states). Therefore, they are called spontaneous transitions. Besides spontaneous transitions, there is also another type of process--

stimulated transition. Stimulated transitions correspond to the process of electrons--induced by photons coming from the outside--transitioning from high energy levels to low energy levels. Over 60 years ago, Albert Einstein pointed out that it was possible for molecules and atoms placed in high energy states to be stimulated to radiate light. This type of stimulation process requires a photon emitted from another light source. The energy of this photon is exactly the difference between stimulated energy levels and low energy levels. In reality, the effect of this photon coming from outside on molecules and atoms in stimulated states is to induce them to give off a second photon of the same kind.

Stimulated radiation definitely is a very unusual process. The reason is that there is only stimulated radiation when a photon of a specified energy is placed at a specific point at a specific instant. In fact, the optimum way to obtain this type of photon is from an energy transition of the same type associated with atoms or molecules of the same type (illegible). Due to operating levels associated with the laws of (illegible) dynamics, gathering together a number of the same atoms and molecules and making them (illegible) the same excitation state is certainly not easy. The central problem is that atom and molecule states always tend toward being placed in the lowest energy level, that is, a base state. In conditions of absolute zero, all molecular motion is frozen. At temperatures above absolute zero, there will be some molecules placed in high energy states. Under ordinary conditions, that is to say, under conditions of thermodynamic equilibrium, the various individual quantities all reach dynamic equilibrium. At this time, the higher energy levels are, the smaller is the number of atoms and molecules placed in this energy level.

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When atoms transition from high energy levels to low energy levels, how do photons act? Due to the fact that the number of

atoms placed in low energy levels is larger than the number of atoms placed in high energy levels, speaking in physics terms, that is nothing else than numerical densities associated with particles placed in low energy levels being larger. Before a photon induces an atom placed in a high energy level to produce radiation, it may meet with atoms placed in low energy levels and be absorbed. Although this is the case, stimulated radiation can still be realized. In the 20 years following, it was definitely observed. However, in the end, because spontaneous radiation drowns it out, it was not possible to make use of this phenomenon of stimulated radiation.

The results are very clear. For many years, physicists saw stimulated radiation as an interesting phenomenon with no practical significance. According to Ase Xiaoluo (phonetic), the problem lay in the fact that "Scientists took the world of equilibrium states which they saw with their own eyes as being straightforward. But, in reality, when placing stimulated radiation in the dominant position, it required completely breaking away from equilibrium states. This was inconceivable at that time."

Because of this, stimulated radiation has conditions. What is required is what is called nonequilibrium conditions associated with particle number reversal, that is, the number of atoms or molecules placed in high energy levels must be more numerous than low energy levels. Chalisi Tangsi (phonetic) made use of physical methods to take stimulated state ammonia and separate it out. Going a step further, he produced the first stimulated radiation amplification microwave system which was called "MASER". The methods he used were appropriate to microwave transitions. With regard to producing high energy transitions associated with short wave lengths--for example, lasers--it was necessary to realize full number reversal, and it

was then not possible to use methods associated with the isolation of stimulated states and required use of other methods.

It was possible to make use of electric currents, strong optical stimulation, and chemical reactions in order to produce atoms and molecules in stimulated states so as to reach particle number reversal. This type of idea involves selectively increasing the numbers of high energy level atoms or molecules. In this way, photons produced in association with stimulated radiation will have more opportunities to meet with high energy level atoms and molecules and to induce radiation. Moreover, the possibility of spontaneous radiation photons meeting with low energy level atoms and being absorbed is very, very greatly reduced. The result is that light goes through stimulated radiation and is amplified. The net number of photons goes up.

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What is worth paying attention to is that stimulated radiation most certainly is not merely capable of being achieved artificially. After the invention of lasers, radio astronomers discovered that high temperature interstellar gas clouds are also capable of producing (illegible) wave band stimulated radiation. The physical processes associated with their production and the physical processes associated with the producing of stimulated amplified microwaves in the laboratory are similar. As a result, there are people who call these interstellar gas clouds cosmic stimulated amplified microwave devices (or cosmic ray masers). What startles people still more is that the atmosphere surrounding Mars is just like a carbon dioxide laser. The total power is estimated to be 5 billion watts. With an external light source--such as hot celestial bodies or sunlight--it is also possible to stimulate the gas, producing particle number reversal. As a result, cosmic stimulated radiation amplified microwave devices and Mars lasers are both possible. Looking at

this, the natural world is certainly not all in states of thermal equilibrium.

4-3 Production of Laser Beams

Particle number reversal is certainly not the whole content of lasers. Stimulated radiation does not merely require particle number reversal. It also requires being able to "amplify" stimulated radiation. As far as particle number reversal is concerned, in order to (illegible) provide the needed conditions for this sort of amplification, it is only with the presupposition of the realization of particle number reversal that it is then possible to make stimulated radiation greater than spontaneous radiation. However, if one wants to realize stimulated radiation, it is still required that, when stimulated luminescence penetrates operating materials, the stimulated luminescence is amplified. Let us consider for a moment, in a body of unrestricted gas, how stimulated radiation operates. For example, in cosmic stimulated radiation amplified microwave devices (that is, masers), the original spontaneous radiation photons induce another atom to emit a photon of the same kind. After that, the two photons which appear both advance along the original direction. When they penetrate gas, it is also possible for them to give rise to stimulated emissions from other excited atoms right on until they penetrate through the gas and then it stops.

As long as there is no material in the gas to reflect light, photons propagate in a straight line beginning from the place where they were produced and along the path of propagation in the gas, going through stimulated radiation in addition to amplification. This being the case, the direction of light emission is random. No specific direction exists--similar to light put out by light bulbs. Of course, this type of light is stimulated radiation light and not natural light. The light

output is concentrated in the wave length area of the stimulated radiation. The emitted light will go in various directions. Emission strengths associated with specific wave lengths clearly show the stimulated radiation characteristics of the light source. Due to the fact that the shapes of gas clouds and the positions of celestial bodies on their peripheries are different, as a result, the emission strengths of cosmic masers associated with certain directions are greater than other directions. There is no similarity at all between this and the beam narrowness and good directionality associated with man made lasers. The operating processes associated with the Martian atmosphere are the same as this. The situation relating to it can be understood upon reflection. If 5 billion watts of laser light are concentrated in a narrow beam, it will be a terrifying natural laser weapon--the pure "terror cannon" of the solar system. In Martian lasers and cosmic stimulated radiation amplification lasers stimulated radiation amplification processes exist in all of them. With that the case, their light is emitted in various directions. There is no way to take high powers and concentrate them within very small areas. But, as chance would have it, this is what is required for laser weapons. In order to explain how to produce high power laser beams, it is necessary to introduce two concepts: laser gain coefficients and laser resonance cavities.

Gain coefficients are nothing else than the degree of amplification when lasers penetrate operating materials. This is a quantitative requirement. It is normally measured by using the amount of amplification achieved passing through a unit length of laser material. The typical gain value is a few percent for each centimeter. If the gain coefficient is 5%, then a laser with a power of 1 watt, passing through a 1 cm thickness of operating material will come to have a power of 1.05 watts. Laser gain has cumulative characteristics. This is entirely similar to compound

reproduction processes. As a result, the longer the distances lasers penetrate are, the larger their powers then are.

Utilizing very long cylinder shaped laser operating materials, producing lasers with very good directionality (or directional altitude concentrations) seems very easy. However, in reality, if one wants to achieve high power laser beams, it not only requires high power, it also requires beam fineness. In order to realize high powers, one can, with a certain gain coefficient, make light penetrate a relatively long distance through operating material. Moreover, one must make the beam cross section small. Then, it is necessary for beam divergence angles to be small. There is a clever method by which it is possible to resolve the problems described above. This is nothing else than placing a mirror at the two ends of the operating material. In this way, light beams are made to be reflected back and forth between the two mirrors. This is then equivalent to light penetrating a very long distance in the operating material, thereby being amplified. The relative /74
positions of the two mirrors determines that amplification is only possible in association with a number of wave lengths of light with (illegible) determined wave lengths. The diameter of the mirrors is determined by the divergence angle of the light beam. Light beam diameter follows along with increases in propagation distances and increases somewhat. As far as the size of the divergence angle is concerned, it is possible to use 1.22 times the quotient from dividing the wave length by the mirror diameter to describe it. This is determined by the laws of diffraction. In this way, the two mirrors form one system called a resonance cavity. The design of resonance cavities is extremely important for good operation of fixed lasers. Design of resonance cavities includes: the size of mirrors, shape, transmission rate, reflection rate, relative geometrical positions, and so on, and so on. In actuality, a laser reflecting mirror (sometimes two reflecting mirrors) is capable

of permitting a small part of light inside the laser to leak out, forming the output light. Generally, it permits a few percent of the light to be transmitted through reflecting mirrors. Because lasers are different, there are very large differences in this ratio. The form in which light is reflected back and forth between the two mirrors will produce effects on one very key characteristic associated with lasers as weapons. This is the distribution of energy within the beams. Beams produced by standard resonance cavities have energies primarily distributed in the centers of their cross sections. However, other design structures will produce different energy distributions. There is one type of structure which can produce ring shaped energy distributions. Beam centers have almost no energy. In this type of situation, lasers can very easily penetrate air and reach targets (see Fig.4-3).

Taking laser energy and concentrating it into a very narrow beam is extremely important when talking in terms of laser weapons. The reason is that it is only in this way that it is possible to make use of limited laser powers in order to destroy targets. Laser casualty producing capabilities are determined by their strength, that is, the magnitude of the energy associated with a unit area. The level of concentration of energy within laser beams is very high. Small model helium-neon lasers like those in high school physics laboratories only produce one thousandth (illegible) (10^{-3}) of a watt of red light. However, if it can be concentrated into a light beam one millimeter in diameter, then the strength will be equivalent to the strength of sunlight. When the ordinary incandescent lamp consumes 100 watts of electricity, it produces approximately 1 watt of light (the rest of the energy is turned to heat and dissipates away). This is adequate to illuminate one room. However, the light strength is very low. Due to the extreme concentration of laser beams, powers which would certainly not be considered large in other /75 situations, are high powers speaking in terms of lasers. Take a

1 kilowatt electric heater and put it into a gloomy, cold room. You are only able to feel heat at distances one or two meters from the electric heater, and you will not be burned. However, a laser with 1 kilowatt power will be a very effective industrial cutting tool. A 300 kilowatt laser is adequate to make laser weapons demonstration tests. The power is 400 horsepower--equivalent to the power of certain large model cars.

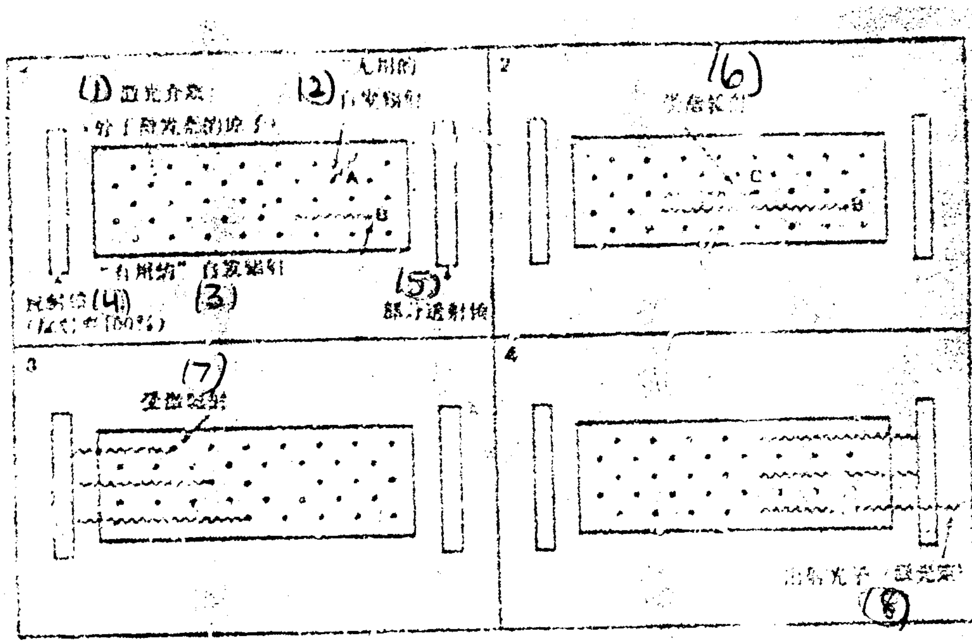

Fig.4-3 Interior Schematic of Laser Paths. Lasers spontaneously discharge (illegible) photons along the axial direction of laser resonance cavities. The light (illegible) produced is reflected back and forth between two reflector plates. One part of the light is split off and transmitted out from a (illegible),

forming a considerable (illegible) laser beam. Another part is reflected by this reflector plate to (illegible) in the laser medium, stimulating even more radiation.

Key: (1) Laser Medium Atoms Associated with (illegible) Molecular Stimulation (2) "Useless" Spontaneous Radiation (3) "Useful" Spontaneous Radiation (4) Reflector Mirror (Reflection Rate 100%) (5) Partially Transmiting Mirror (6) Stimulated Radiation (7) Stimulated Radiation (8) Emitted Photons (Laser Beam)

Laser beams are certainly not strictly directional. Theoretically speaking, this is also the case. However, the expansion of laser beam diameters is very slow. Angles of spread are related to resonance cavity structures as well as all the optical system types associated with light output. The normal expansion angles for small model helium-neon lasers are 0.01 radians (1 milliradian is 0.06°). This angle corresponds to an expansion angle of one part in one thousand, that is, a light beam with a diameter of 1 millimeter, after propagating 1000 meters, would expand to a diameter of 1 meter. Using modern advanced optical systems, it is possible to take this type of divergence and reduce it to 1/100th of a milliradian. In this way, beams propagating a million meters (1000km) would have light diameters only expand to 1 meter.

As far as minimum limits set by the laws of refraction are concerned, they are not only appropriate for use with light beams which are very finely converged initially. They are, moreover, also appropriate for use in cases with gross beam diameters. That is to say that, no matter whether beam diameters are gross or fine, the magnitudes of their angles of divergence are all the same.

4-4 Raising Laser Powers

The earliest lasers were only capable of producing low power continuous beams or equivalent weak pulse beams. Not long after, physicists began carrying out research on raising laser powers. A milestone associated with laser development was their ability to bore a hole in a razor blade. Due to the fact that sustainment periods for strong laser pulses used to bore holes can be very short, power measurements are very difficult. Because of this, laser research personnel then used a famous razor blade brand--Gillette--to be the unit in order to measure laser power. One Gillette of power is equivalent to a pulse power capable of boring a hole in a razor blade.

The operating material associated with the first laser was synthetic ruby crystal. In 1969, it was first built by the American Mamen (phonetic). Ruby lasers are a relatively typical form among several important laser types. In this kind of laser, medium atoms in transparent crystal rods or inlaid in glass receive optical irradiation from external light sources (normally this is a flash lamp) and are stimulated. Because of this, /77 particle number reversal is produced in the rod. If one puts reflecting mirrors at the two ends, it is possible to use it as a laser. The pity is that only a very small part of the light energy entering the rod (generally around 1%) can be turned into laser light. The other large part, by contrast, is turned into heat and is dissipated away. This heat must be eliminated in order to avoid beams or rods themselves receiving high temperatures and (illegible) damaged.

In ruby lasers, getting rid of heat is a very key problem. Despite the fact that external light source energies accumulated within rods are very small, in heat insulated solids, however, excessively slight amounts of heat are lost very slowly. It is very easy to produce temperature rises. Based on this fact, as

well as the complexity of energy levels in materials, this type of laser is only capable of use in situations associated with very low powers. Moreover, output of only a few pulses per second is permitted. In this way, actual output powers associated with this type of laser are very, very greatly limited. Normally, the higher pulse powers are, the longer will be the required time intervals between two pulses in order to avoid excessively high temperature rises. There are a number of lasers made using glass and other crystals with higher efficiencies than ruby lasers, moreover, they are very easy to cool. However, they all have one important problem, that is, volumes are not large. As a result, power outputs are also not large.

Crystal or glass lasers are capable, within very short pulse durations, of producing very high powers. However, this type of laser is only capable of being used in inertia binding nuclear fusion research and is not capable of being used in the weapons area. For example, in the already terminated SHIVA laser system at the U.S. Laurence Livermore national laboratory, it was possible to produce powers of $2x10^{13}$ watts (20 thousand billion watts). However, the sustainment period was only $2x10^{-10}$ seconds (see Fig.4-4). From the point of view of weapons, there is a problem. That is nothing else than that this type of laser is not convenient for regular ignition and firing. In the case of a huge laser with twenty beams, it occupies a four story building. In 1979, there was an average of approximately one firing a day. With regard to fusion research, this is not bad at all. However, if there is a missile coming in, that would be hard to deal with. The Soviet Union has already produced a number of models of crystal lasers. However, limiting factors still exist. Crystals are a great help in research which is unrelated to weapons. However, nobody expects to use them in the weapons area. At least, it is this way in the U.S.

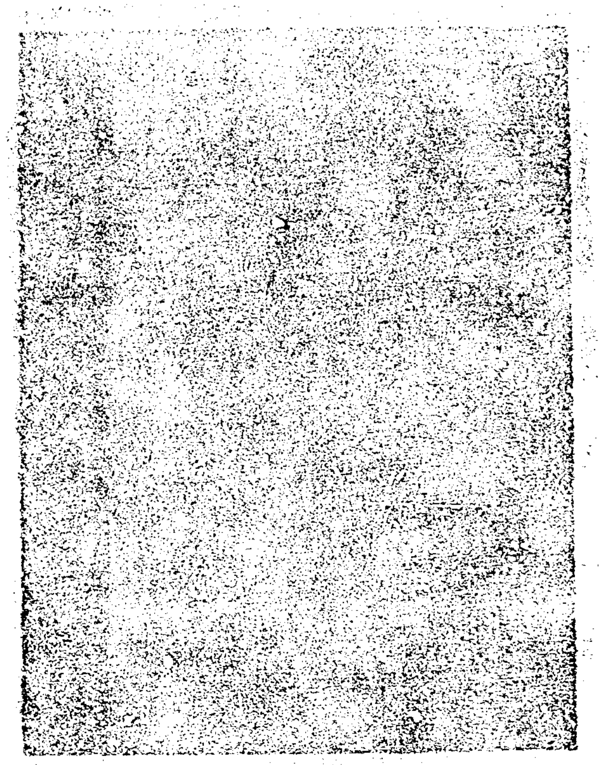

Fig.4-4 (Illegible) Watt Laser System at California's Laurence Livermore National Laboratory. In the Fig., there are 6 tubes from among 20 tubes. This solid state laser system is used in research on the area of laser nuclear fusion. This already eliminated (illegible) occupies the entire (illegible) building. Within an extremely short pulse duration, it is capable of releasing (illegible) high power laser. A type of (illegible) new laser system is just in the midst of replacing this (illegible) system in order to obtain even higher power laser beams.

In order to make lasers capable of operating at high efficiencies, it is necessary that laser operating material be able to effectively get rid of waste heat during laser operations. Considering gases, they must be capable of rapidly and effectively flowing within lasers. In conjunction with this, they must be able to carry out excess heat. As a result, gases are very suitable operating materials. Making gases rapidly flow, even to the point of eliminating the gases, is very key to the raising of laser powers. At this point, there is some similarity to jet engines. Besides free electron lasers and X

ray lasers (will be introduced later), all other relatively mature high power lasers are dependent on the status of gas flow. The first continuously operating gas laser was the helium-neon gas laser built in 1960 by Yawen (phonetic), Benneite (phonetic), and Helioute (phonetic). However, the power was not figured to be large.

/79

4-5 Carbon Dioxide Lasers

The first high power gas laser was the carbon dioxide laser. It was demonstrated in 1964 by Kumaer (phonetic) and (illegible)tele (phonetic) of the U.S. Bell Laboratories. Carbon dioxide lasers are capable of producing invisible infrared light of 10.6 micron wave length. The wave length is 20 times the wave length of visible light. This type of laser is not only technically very simple. Moreover, its efficiencies are high. It is capable of taking approximately 20% of imputed energy and turning it into laser output. The light beams produced can be continuous or pulse. In dry air, 10 micron wave length light propagation properties are very good. Due to these advantages, carbon dioxide lasers achieved broad applications in several fields including cutting and welding. Various models of carbon dioxide lasers were associated with output powers of 1-20000 watts.

Patele (phonetic) used electric current put through pure carbon dioxide in order to produce laser beams. In discharges, high speed movements of electrons take energy and transfer it into molecules giving rise to molecular vibration. After lose of molecular stimulation, photons are then given out (see Fig.4-5). When carbon dioxide molecules fall to relatively low vibration energy levels, these molecules emit a number of photons with wave lengths in the vicinity of 10 microns. Gas electrical discharges make large numbers of molecules excite to relatively high vibration energy levels, producing particle number reversal.

This makes laser light produced at this wave length become a possibility (In reality, there are two vibration transitions and several tens of types of rotation transitions. These transitions combined together make it possible to produce approximately 100 types of different possible laser transitions. As a result, there are also a like number of wave lengths. A number of low power carbon dioxide lasers only emit one type of wave length. Generally, 10.6 micron transitions are selected to realize laser emission. As far as actual lasers are concerned, it is necessary to add in (illegible) gas in order to raise energy transformation efficiencies. Nitrogen gas is a supplementary gas. When nitrogen molecules stimulated by the absorption of energy in electrical discharges collide with carbon dioxide molecules--because energy level intervals associated with these two types of molecules are very close--nitrogen molecules (illegible) will stimulate energy transmission to carbon dioxide molecules, making particle numbers associated with high energy level 001 even /80 greater thereby leading to more intense particle number reversal.

Laser physicists also studied taking helium and adding it to this mixture of gases. Helium atoms play a special role. They impel carbon dioxide molecules to destimulate from the 10 micron transition low energy level (100), raising the degree of particle number reversal thereby avoiding accumulating numbers of low energy level molecules and absorbing 10 micron wave length photons. This also avoids laser operational suffocation. Besides this, helium can also play a cooling role. In this way, after adding in nitrogen gas and helium gas, it will make the efficiencies of carbon dioxide lasers several times higher than other gas lasers (several orders of magnitude higher than solid lasers). Laser gas components are definitely key factors in /81 lasers operating well or badly. Different laser designs have different ideal gas constituents. Gas pressure is also a very important factor. The energies required by continuous beam lasers and gas pressures required in thermal transformation

processes are best in ranges of from one percent to a few percent of atmospheric pressure. Pulse carbon dioxide lasers are capable of operating at roughly ten times atmospheric pressure.

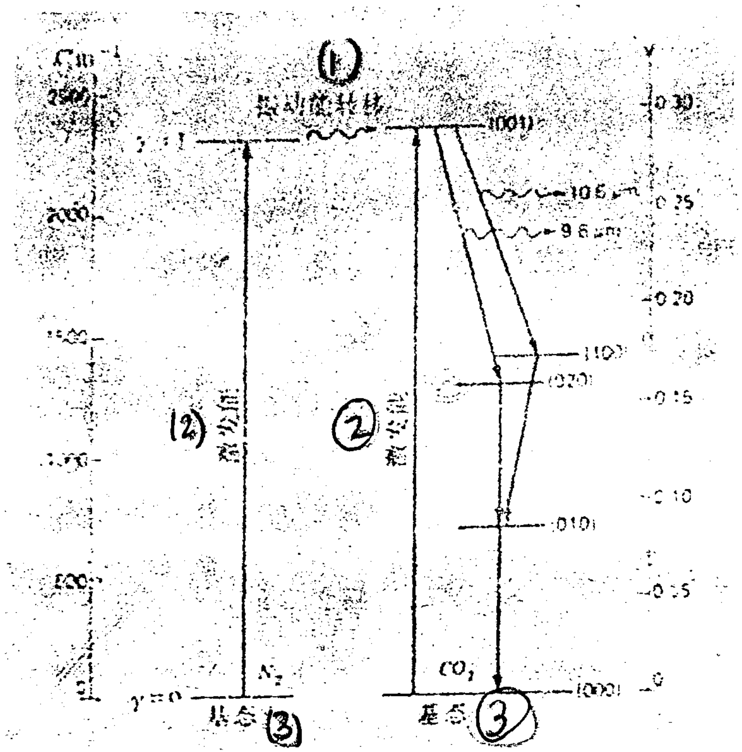

Fig.4-5 Carbon Dioxide Laser Energy Level Diagram. It clearly shows that there are many high energies which are only then capable of selective absorption by nitrogen molecules. In conjunction with this, there is transfer to carbon dioxide molecules thereby stimulating the emission of two lines of infrared light with wave lengths close to 10 microns.

Key: (1) Vibration Energy Transfer (2) Stimulation Energy
(3) Base State

Patele (phonetic) as well as the colleagues who developed the first generation of carbon dioxide lasers with him made this kind of experiment. They took gas and filled up a long tube, making the gas flow. Moreover, they discharged electricity along the long tube. Following that, they discovered that a limiting condition was very quickly reached. The cause is that long, thin

conduits limit amounts of gas flow. As a result, pollutants and waste heat produced by electrical discharges are eliminated very slowly. Optimum emission powers are 100 watts for each meter of tube length. Continuing to increase tube length, powers associated with tube lengths follow along and drop. In the 1960s, the maximum power associated with this kind of laser was 8800 watts, and overall tube length reached 230 meters. Obviously, this cannot be used on the battlefield.

4-6 Gas Kinetic Lasers

According to the definition of Pentagon officials, lasers with continuous beam powers greater than 20000 watts are called high power lasers. Following along with the appearance of one type of carbon dioxide laser called a gas kinetic laser, it was only then that there was a breakthrough in technical problems associated with high power lasers. This designation as gas kinetic lasers originates from the gas kinetics properties associated with producing particle number reversal. It utilizes gas electrical discharges and gets energy from hot gas compounds. Relying on thermal stimulation, it places particles in stimulated states. Through adiabatic expansion, particle number reversal takes shape. Such fuel gases as carbon monoxide are burned in oxygen or oxides of nitrogen, producing high temperature gases associated with thermal equilibrium at several thousand degrees. Their pressures are higher than atmospheric pressures. They can sometimes reach several tens of atmospheres pressure. Through a special nozzle, they are shot into an environment close to /82
vacuum. Rapid expansion causes gases to cool. If this type of expansion cooling process is even faster than processes associated with spontaneous radiation of stimulated molecules, it will then produce particle number reversal.

The mechanism for the realization of particle number reversal through carbon dioxide molecule adiabatic expansion is like this: before expansion, gases are placed in a high temperature thermal equilibrium state. Energy associated with carbon dioxide molecules is distributed in obedience to Boltzmann distributions. At this time, both numbers of molecules in upper energy states and numbers of molecules in lower energy states are very large. At times of adiabatic expansion, gas rapidly cools within 10^{-6} seconds. As a result, molecules associated with the two energy states 001 and 100 will all return to the base state. However, the life of energy level 001 is long--10^{-3} seconds. But, the life of energy level 100 is only 10^{-6} seconds. Because of this, expansion (illegible) particle reversal. Gas flows are very fast--faster than the subsonic speeds of the atmosphere (that is, supersonic speeds). However, particle number reversal sustainment periods are certainly not long, appearing only when (illegible) penetration in air. The sustainment periods make gas flows capable of penetrating a few centimeters within laser cavities. At the two ends of areas associated with the appearance of particle number reversal, two resonance reflector mirrors are placed. In this way, we are then able to obtain energy in the form of light beams.

During the operating processes of gas kinetic lasers, the size and shape of gas kinetic laser nozzles is very key. Gas constituents are also very important. It is possible to get help from nitrogen gas to make energy transfer to carbon dioxide molecules. Help is also required from certain gases in eliminating low energy molecules. Otherwise, they will absorb 10 micron radiation. At the time of the first appearance of gas kinetic lasers, they were capable of reaching startling powers. Measuring by 1976 standards, this was particularly true. The first declassified articles reported that the powers associated with this type of laser were 60000 watts. Theoretical calculations clearly show that, from each kilogram of gas lasers

(illegible), it was possible to obtain several thousand Joules of heat energy. Following that, research personnel (illegible) raised powers to several hundred thousand watts. Gas kinetic lasers were used in laser weapon demonstration experiments. At the moment, a 400 hundred thousand watt gas kinetic laser associated with U.S. Air Force laser laboratories is perhaps the unit with the largest power.

/83

Following along with the development of gas kinetic lasers, a number of problems came to the fore. One among these was efficiencies lower than other carbon dioxide lasers. The reason was that it was necessary to get rid of a lot of (illegible). Secondly, in the atmosphere, it was not possible to propagate this type of light wave length very well. Besides that, gas kinetic lasers were heavy and complicated. When designing and building key components, permissible errors were very small. In an informal discussion meeting at (illegible) engineering institute, a research worker summed up this problem, calling gas kinetic lasers "a ten ton wrist watch". This is a very severe problem. The Pentagon, thereafter, did not put gas kinetic lasers or other continuous beam carbon dioxide lasers into development plans for high power lasers.

4-7 Electrically Stimulated Carbon Dioxide Lasers

There is one type of carbon dioxide laser which is beginning to show promise in the competition for weapons applications. This is none other than a type of advanced, electrically stimulated model of carbon dioxide pulse laser (see Fig.4-6). Among "crosswise flow" type structures, the direction of gas flow, the direction of electrical discharge, and the direction of resonance (illegible) mutually perpendicular. As in the case of "lengthwise flow" types, electrons produced using gas electrical discharges or high energy electrons going through collision take

energy and transmit it to gases. Crosswise flow type structures can easily eliminate contaminants. Among products in the marketplace, powers associated with each meter of resonance cavity length can reach 10 kilowatts. This type of method is used in commercial lasers and is capable of producing powers from a few kilowatts to twenty kilowatts. As a result, they can be used in weapons experiments as well as metal working and other industrial applications.

In the same way as gas kinetic lasers--among crosswise flow carbon dioxide lasers--gas flows are also very key. In Suomaiweier (phonetic) Massachusetts, in the U.S., the Yafuke Aimiruite (phonetic) Company produces metal working lasers. They used a component called a "wind tunnel" from a 10 kilowatt high power laser they produce and avoided a number of problems which exist in electrically stimulated gas kinetic lasers--in particular, low powers as well as a number of technical problems leading to operating complexity. The U.S. Army is in the midst of considering taking electrically stimulated carbon dioxide lasers and using them on the battlefield.

The biggest problem with electrical stimulation methods is the need for a power source. On the battlefield, it is not possible to lay electrical power source lines. As a result, laser weapons must be equipped with their own electrical power sources to use. Electrical power sources are huge and unwieldy. It is possible to imagine this type of situation: on a laser weapon battlefield, various individual small, clever lasers connected, through various individual large thick electrical cables to various individual large, unwieldy electric power sources. There are some engineers who put forward the idea of taking laser weapons and installing them on a small model fighter plane, and--flying at the side of the battlefield--a huge jet aircraft is its power source. On the battlefield, the possibility exists of separating electrical power sources and

lasers. However, there are a number of complicated problems which must be solved. In a small pamphlet published by the Pentagon and called "Soviet Military Power", an artists /85
conception of battlefield laser weapons is presented: two military installations that look like tanks. One is equipped with
a laser weapon, and the other has the power source. The two use electric cable to connect themselves.

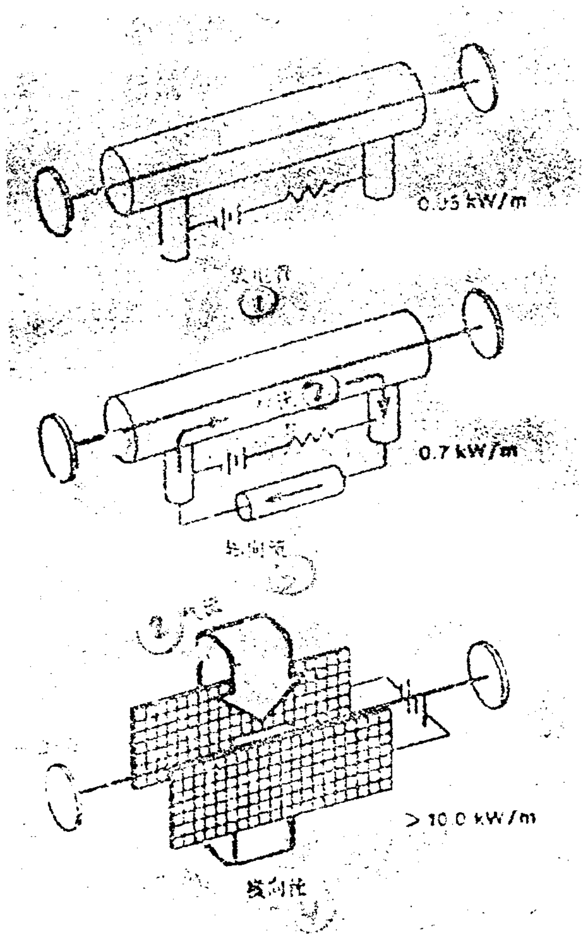

Fig.4-6 A Kind of Structural Diagram of Three Types of Carbon Dioxide Lasers Classified in Accordance with Output Powers of Approximately a Thousand Watts for Each Meter. As far as the electrically stimulated tube at the top is concerned, because it is not capable of making gases (illegible) across the tube, laser beams produced are, therefore, quite weak. Lasers with gas flow along the axial direction of the tube are capable of producing relatively high power laser beams. If one wants to obtain the highest power laser beams, gas flow directions must then satisfy, at the same time, the requirements of being perpendicular to the axial direction of the laser beam and the direction of electrical discharge, as shown in the bottom most diagram.

Key: (1) Electrical Discharge Tube (2) Gas Flow (3) Lengthwise Flow Direction (4) Crosswise Flow Direction

Developing high power lasers that can be used in outer space and electric power sources that supply electricity (illegible) other installations is very valuable militarily. The Defense Advanced Research Planning Agency (DARPA) is in the midst of investing in a hundred thousand watt nuclear generator, hoping, in the end, to manufacture an electric generator with a million watts of power to use in outer space.

4-8 Carbon Monoxide Lasers

Here, it is worth bringing up another type of electrical stimulation model laser--carbon monoxide lasers. The operations of this type of laser and carbon dioxide lasers are very similar. They will produce transition radiation associated with the superposition of a set of vibrations and rotations. Wave lengths are approximately 5 microns.

What is most attractive to people about carbon monoxide lasers is their high efficiency. Theoretically, they have the highest efficiencies among electrical stimulation gas lasers. Efficiency measurements have been carried out in the laboratory. However, calculations were not carried out using the same methods used to calculate the efficiency of carbon dioxide lasers. Actual powers of carbon monoxide lasers taking imputed power and turning it into laser power will be much lower than results obtained in the laboratory. High power is produced. However, carbon monoxide lasers--when used to act as laser weapons--have two fatal flaws. One is that water vapor and other gases will intensely absorb 5 micron wave length light. This problem does not exist with regard to either visible light or 10 micron wave length carbon dioxide laser light. Besides this, in order to operate effectively, lasers must operate at temperatures of 77K-100K (-230°C -- -200°C), that is, at low temperatures where nitrogen and oxygen become liquids. There are severe problems

with regard to the requirements that low temperatures bring. Military research personnel have no choice but to discard the idea of opting for the use of carbon monoxide lasers.

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4-9 Chemical Lasers

In the process of selecting laser weapons, chemical lasers have a decisive position. As the name suggests, chemical lasers get energy from chemical reactions--for example, hydrogen gas and fluorine gas react to form hydrogen fluoride (HF) molecules in states of vibratory stimulation. Hydrogen fluoride lasers are just one member in the large family of chemical lasers. Normally, what are designated as chemical lasers are hydrogen fluoride lasers including those using the natural isotope of hydrogen--deuterium--to replace hydrogen. The laser light produced by this type of deuterium fluoride laser has very good propagation characteristics in air (see Fig.4-7).

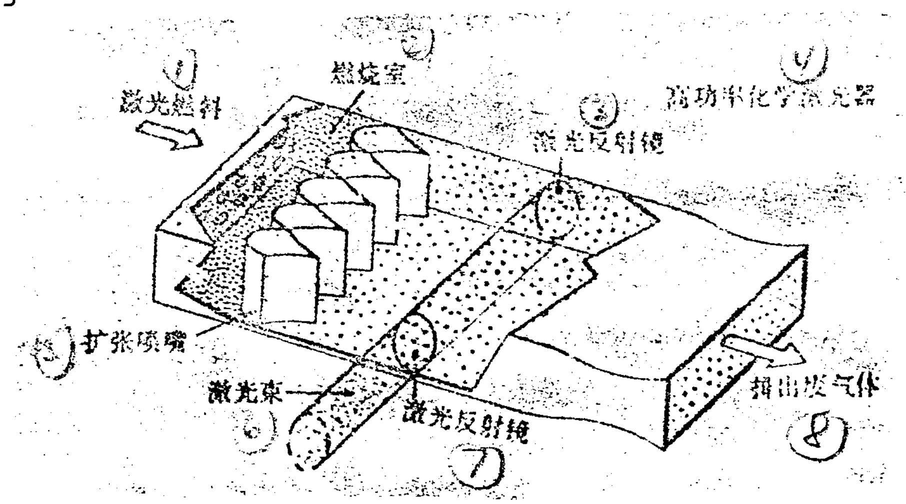

Fig.4-7 Schematic Diagram of Chemical Laser Operating Principles. After laser fuel is burned in the combustion chamber, it goes through expansion nozzles. When hot gases rapidly pass through, from between the two laser reflector Mirrors, there is then a laser energy output.

Key: (1) Laser Fuel 2) Combustion Chamber (3) Laser Reflector Mirrors (4) High Power Chemical Laser (5) Expansion Nozzles (6) Laser Beam (7) Laser Reflector Mirror (8) Exhaust Waste Gas

Reactions in chemical lasers are capable of being set off by electrical discharges. However, this reaction process is the simplest pure chemical reaction process. Initial use is made of oxidizer fuel containing hydrogen and fluorine acting as laser medium. Sometimes, pure hydrogen and fluorine are also used. However, these two types of gases are very difficult to handle. This is particularly the case with the very strong toxic chemical reactivity of fluorine. This dangerous nature makes chemical laser builders feel extremely inconvenienced. They frequently half jokingly talk about "this week's fire" as the topic of /87 conversation. The reason is that it only needs gas to leak and there will then be the danger of fire. Fluorine gas also has the characteristic of being able to make stainless steel containers explode making people afraid. Due to the existence of these problems, laser developers lean toward the use of compounds of fluorine and hydrogen which are easily handled and discharged when necessary. As a result, a fuel which can offer a choice is hydrocarbon compounds (for example, alcohol) and the added oxidizer of nitrogen trifluoride.

The first step in chemical lasers producing laser light is to make the fuel and the oxidizer respectively release free atoms of hydrogen and fluorine. This is a preparatory reaction in which only small amounts of fuel and oxidizer participate. The result is to supply adequate high reactivity atoms so as to set off continuous chemical reactions. After that, fuel and oxidizer gases go through a set of nozzles similar to gas kinetic lasers. After mixing of rapidly moving gases, reactions occur, producing vibration stimulated states of hydrogen fluoride. If the reacting substances are pure hydrogen and fluorine, then reactions become self-sustaining chain reactions:

$$H + F_2 \rightarrow HF^* + F$$
$$F + H_2 \rightarrow HF^* + H \rightarrow \text{无限进行下去 (1)}$$
$$H + F_2 \rightarrow HF^* + F \rightarrow$$
*表示激发态 (2)

Key: (1) Carried Right Out Without Limit (2) Stands for Stimulated State

In these reactions, each pound (0.45 kg) of reaction material is capable of producing 500 thousand Joules of heat. In that, most can be turned into laser beam energy. In fast flowing gases, this reaction is capable of producing particle number reversal. When gas flows through a pair of laser light reflecting mirrors, a laser beam is then formed. Rapidly cooled gases very quickly penetrate through from the sides of the two reflecting mirrors, finally entering into the exhaust gas system. So long as gas flow is maintained, lasers will then be able to produce continuous laser beams.

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Here, there are also a number of complicated problems existing. Low gas pressures must be maintained within gas flow cavities. The value is roughly one percent of atmospheric pressure or even lower. It is necessary to set up methods so as to (illegible) gases passing laser reflecting mirrors. In outer space, this is very simple. Add a gas hole, and that will do it. On the ground, by contrast, that will not do. Gas pressure differentials will cause operating complications. Exhaust tubes connected to low pressure cavities will not cause HF elimination and will draw air in. Because hydrogen fluoride, when at concentrations of three percent, is then clearly toxic, it is, therefore, necessary to use a vacuum pump to draw out gases. In conjunction with this, gases are compressed into a sealed container for safe keeping. In battlefield applications, Army units need to take waste gases and compress them into storage canisters in order to avoid inadvertently turning laser weapons into "chemical weapons" aimed at the soldiers operating this type of weapon.

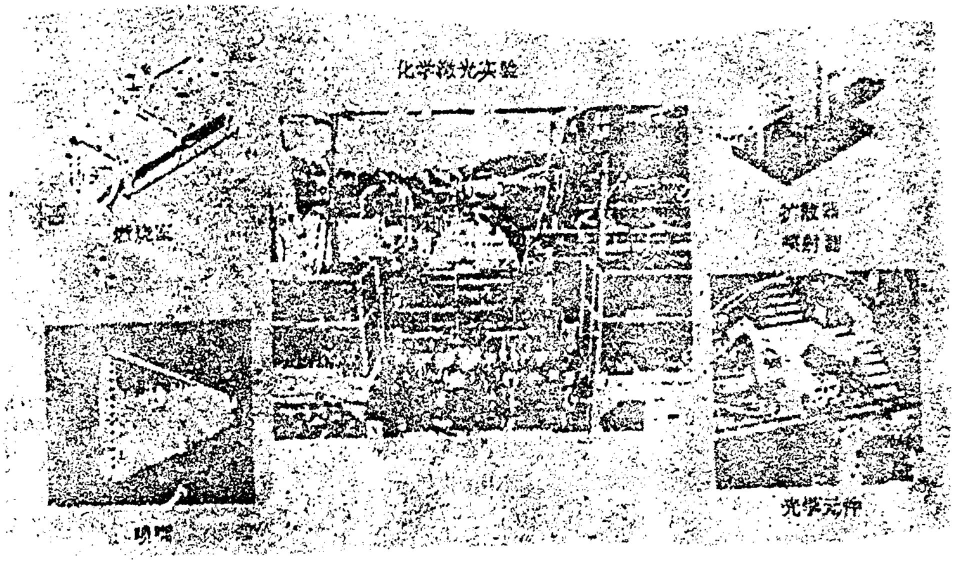

Fig.4-8 In High Power Lasers, A Good Number of Key Components All Have Influences on Gas Flow. The Fig. shows the 100 thousand watt RACHL chemical laser manufactured by Rockwell International's Rocketdyne Company. Combustion chambers, nozzles, diffusers, or injectors are all used in order to control gas flows. The right bottom is optical component parts. (Illegible) in the center of the photo, it is possible to see that gas tube components play very important roles in the entire device.

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In the same way as carbon dioxide lasers, HF lasers are also capable of producing multiple types of light wave lengths combined from sets of vibratory and rotational transitions. Due to the fact that vibratory energy levels are dependent on the masses of atoms composing molecules, as a result, wave lengths emitted by laser devices also depend on atomic masses. It is, therefore, possible to use isotopes of hydrogen atoms to produce different wave lengths. If use is made of the commonest isotope, hydrogen-1, then hydrogen fluoride lasers will emit infrared light with wave lengths of 2.7 - 3.0 microns. If use is made of

the rarer stable isotope deuterium (hydrogen-2), then, hydrogen fluoride lasers will emit infrared laser light of relatively longer wave lengths. The wave lengths are 3.6 - 4.8 microns.

When used in the atmosphere, wave length factors are very important. The wave length of deuterium fluoride is right in the atmosphere "window". This window is (illegible) clear for visible light. However, relatively short wave length laser light produced by hydrogen fluoride will still be intensely absorbed by the atmosphere. Deuterium is a rare isotope. It only accounts for 0.015% of naturally occurring hydrogen. As a result, it is unusually valuable. However, its transmission characteristics, with regard to laser weapons used in the atmosphere, are still very key. Hydrogen fluoride lasers are suitable for outer space. However, if lasers are required to penetrate the atmosphere, deuterium fluoride is on type of appropriate choice in that case (see Fig.4-2).

Speaking in terms of laser system manufacturing personnel, what is fortunate is that hydrogen fluoride lasers and deuterium fluoride lasers are very similar. Among certain low power lasers, these two types of gases are mutually interchangeable. Speaking in terms of high power lasers, despite their operating status being secret, it can, however, be imagined that these two types of gases are not necessarily capable of being easily switched.

Seen from a military point of view, chemical lasers have quite a few advantages as compared to carbon dioxide lasers. One is that energy can be stored in concentrated chemical form and is not stored in the form of electricity. This point, whether it is in regard to utilization on the battlefield or in space, is very important in both cases. On the battlefield, there is a need for light equipment. It is possible not to use power source lines. In space, light weight and small volume are absolutely necessary. Chemical fuel can be stored in high pressure canisters. This will be much easier to handle than large electricity sources. Besides that, one advantage is short wave length. This is /90 capable of avoiding atmospheric absorption. This point is also

very important. Minimum laser faculae on targets depend on the wave length divided by the diameter of output optical systems. If 3 micron chemical lasers and 10 micron carbon dioxide lasers use the same reflector mirrors, then, the diameter of focus points associated with chemical lasers are only 30% those of carbon dioxide lasers. Areas are 9% of carbon dioxide lasers. Power densities on targets will then be raised 11 fold. This is very important because, the higher power densities are (even on relatively small areas), the more capable lasers then are of producing lethal destruction on targets (Of course, it is certainly not always so. Speaking in terms of certain targets, using low power densities to irradiate large areas can be better.) However, when wave lengths are short, there is not only a requirement for high optical precision and very good position control, but prices are also high. Chemical laser research is concentrated on studying continuous beams. However, one series of short, strong pulse light beams may more easily destroy targets, being, moreover, more capable of avoiding encounters with several problems in transmission. This type of technology is similar to technology adopted in chemical lasers associated with the production of continuous beams. However, there are some important differences.

Normally, pulse light beams are set off by flash lamp optical pulses or electron beam pulses produced by particle beam generators. Laser gases burn at room temperature and standard atmospheric pressure. However, under the effects of laser pulses with sustainment periods of a few microseconds, chemical reactions are capable of taking gas temperatures and raising them to 1000°F. Pressures rise to 6 atmospheres. In demonstration experiments, it is possible to produce 50 pulses per minute.

Pulse chemical laser technology is not as mature as carbon dioxide lasers and continuous beam chemical lasers. One key problem is the production of sound waves. This type of sound

wave will cut beams, destroying gas flows as well as optical component collimation. These several factors above are all very key in laser weapon applications.

4-10 Short Wave Lasers

Despite the fact that Pentagon policy makers are willing to opt for the use of chemical lasers, they wish more, however, to have lasers with shorter wave lengths. When used in outer space, this is even more the case. Several special missions require /91 laser beams--after penetrating distances of several thousand kilometers--to still be able to form very small faculae on targets. This type of property is very crucial. The most ideal lights they hope for are visible light (0.4-0.7 microns) or ultraviolet light (0.01-0.4 microns).

Chemical lasers are relatively mature. Their principles are also relatively clear. This is nothing else than an important site of attractiveness associated with this type of laser. With regard to lasers with pulse sustainment periods on the order of seconds, powers already reach several million watts. This type of pulse sustainment period is adequate for application to military purposes. This type of technology is ready made. However, it still has a long distance to go to be used on the battlefield or used in satellites.

Short wave laser technology is a type of new technology. Its potential is still not very clear. In this area, the Pentagon has already spent several years of time and a few million U.S. dollars in funds. (Illegible) people universally believe that short wave lasers are five to ten years behind chemical lasers. Among short wave lasers, there are already four objects which can be selected: (1) oxygen--iodine chemical lasers; (2) quasimolecular lasers; (3) free electron lasers; and, (4) X ray lasers. Each type of laser has its own advantages

and disadvantages. However, there is not one type of laser the properties of which compare to chemical lasers.

4-11 Oxygen--Iodine Chemical Lasers

Oxygen--iodine chemical lasers are sometimes also called COIL. They are a new model of laser with fine prospects on the chemical laser stage. The 1.3 micron near infrared laser beam which it produces is transmitted quite well in air. Its wave length--despite the fact that it is not as short as some researchers expected--is still adequately short, however. Needed optical component diameters are only half to one third of hydrogen fluoride or deuterium fluoride lasers. Researchers hope that COIL efficiencies and powers will be adequate to compete with contemporary high power chemical lasers. At present, their powers have already reached a few million watts. /92

In reality, this type of laser is an early variety of iodine laser. In this type of early laser, use is made of strong ultraviolet light which will contain iodine molecules colliding, producing iodine molecules in a stimulated state. In conjunction with this, it is capable of putting out 1.3 micron light. Energies associated with this type of laser come from strong flash lamps. In the middle 1970s, at the Max Planck research institute in West Germany, it was already possible to produce sustainment periods of 10^{-9} seconds. Peak powers were laser pulses of 10^{12} watts. In conjunction with this, they were utilized in order to carry out nuclear fusion reaction experiments.

Flash lamps are only capable of producing light of limited power. Moreover, their volumes are large, and they break easily. In applications as laser weapons, they are not very effective. In the past few years, laser scientists have also discovered

another type of method to produce atoms in stimulated states. This type of method is to make use of oxygen molecules in stimulated states produced by chemical reactions to transmit energy. This type of iodine chemical excitation laser is capable of producing continuous beams or producing pulse beams with sustainment periods of 10-(illegible) seconds.

Chemical iodine lasers certainly are not the weapons the Pentagon was hoping for. Although their wave lengths are short, they were hoping to use liquid fuel--which is easier to handle than hydrogen and fluorine--for operations. Due to their having these types of special characteristics, they are very attractive to military people. At the present time, this type of laser has gotten quite a large amount of support--in particular, support from the U.S. Air Force. Research targets lay in finding optimum fuel types and resolving instability factors associated with transmission in air.

Looking at this type of technology, its development has been very smooth. In 1980, the Air Force weapon laboratory at Kirtland Air Force Base in New Mexico was entrusted with two very important high energy laser research units--the TRW Company and Bell Aviation Company built an iodine laser with an output power of 50 thousand watts in 1982. Since 1982, the results of these projects has been encouraging. In order to study iodine oxide lasers which require supersonic gas flow technology, close to two million U.S. dollars were invested. Investments on this scale, in a certain sense, betoken wanting to build a large model laser.

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4-12 Quasimolecular Lasers

Dependent on the one point of chemical reactions between two atoms, there are points of similarity between quasimolecular lasers and chemical lasers. However, strictly speaking, they are

not basically chemical lasers. Their energy does not come from chemical reactions. They are, however, electron beams associated with gas electrical discharges or fired toward gases. A number of energy transmission methods are also possible, such as microwave stimulation. This term quasimolecular originally only referred to a pair of atoms with the same nucleus, for example, Ar_2++ or Kr_2++ . They only exist in a stimulated state. However, they are now also universally applied to heteronuclear or multiple atom molecules. Quasimolecular lasers which have become commercial products all use rare gas halogenides to act as laser material--for example, ArF++ (193 nanometers), KrF++ (248 nanometers), KrCl++ (222 nanometers), XeF++ (351 nanometers), XeC_6++ (308 nanometers) (1 nanometer = 10^{-9} meters = 10 (illeg.)).

Quasimolecules are two atoms bound together when molecules are placed in stimulated states. When molecules lose stimulation and drop to the lowest energy levels, the two atoms separate from each other. This means that, at the lowest energy levels associated with laser transitions, no quasimolecules exist. As a result, so long as quasimolecules exist, there will then be particle number reversal. This condition is suited to the production of high power ultraviolet pulses.

The most famous, most important quasimolecules are those containing halogen atoms (for example, chlorine and fluorine) as well as rare gas atoms (for example, xenon and krypton). Due to the fact that their outer electron shells are normally full, as a result, this type of gas is not reactive. When they are stimulated, there is one outer layer electron alone positioned in a shell layer, causing the atom to be very reactive. When mixtures containing laser gases are stimulated by gas electrical discharges or beams, then quasimolecules are formed. The two most important types of quasimolecule laser weapons are both /94 ultraviolet light types. Kypton fluoride laser wave lengths are 0.25 microns. Xenon fluoride laser wave lengths are 0.35

microns. The definition of laser efficiency is the percentage of output energy turned into laser energy. Efficiencies associated with these two types of lasers can reach 10% and 5%.

From the middle 1970's, after the appearance of quasimolecular lasers, this type of laser technology achieved rapid development. However, a number of important problems still exist. Due to the fact that the lives of quasimolecules are short, this type of laser generally only produces pulse beams. This is certainly not suitable for laser weapons. Pulse operating states will produce sound waves, making laser beams break up. Quasimolecule lasers are even more sensitive to this problem. The reason is that, when wave lengths are short, it makes the influences of small divergences greater. A number of problems also exist associated with ultraviolet light optical components. Just as a certain observer said, high strength light beams of this type of wave length "are capable of smashing any material." Taking output powers and raising them to the level of chemical lasers is a matter of very great ingenuity. Their average maximum powers are still smaller than one one thousandth of maximum chemical laser powers.

The Pentagon's original interest lay in taking quasimolecular lasers and using them in outer space. Possibly later a new type of capability would appear. This is nothing else than taking lasers and putting them on the ground, using light beams to reflect onto targets from orbiting focusing mirrors. This type of thinking is certainly not new. Due to the requirement for beams to penetrate through the atmosphere to reflectors, as a result, it was shelved early on. This idea is receiving attention again. This is certainly not merely due to laser weapons. It is because there is a new type of laser project: utilizing blue green laser beams to transmit information to submarines. Research personnel associated with this project faced severe difficulties in building blue green

lasers which were capable of reliable operation in space. In order to resolve this problem, research personnel opted for this plan--take laser positioned on the ground and reflect laser beams off orbiting reflector mirrors.

Applications in the weapons area can also be built on the same fundamental idea. It is only necessary to use relatively high power lasers. That is all. The lasers themselves can be built on high mountains. On high mountains, clouds are very rare, and the atmosphere is stable. For example, putting lasers on mountains in Arizona or New Mexico makes a good number of /95 things (illegible) much easier to handle. This makes it possible to avoid taking a very large power source and installing it in outer space orbit (this is an obvious flaw associated with electrically stimulated quasimolecular lasers). Placement of lasers on the ground also makes maintenance as well as replacement of operating media easy. However, problems of atmospheric absorption and scattering still exist. The effects of these types of influences on laser weapons will be greater than the influences on communications lasers. Atmospheric influences on short wave band ultraviolet are obviously very severe. Xenon fluoride lasers are capable of operating very well on the ground. However, the intense absorption makes people even less interested in them than in krypton fluoride lasers.

4-13 Free Electron Lasers

In the middle 1970's, not only quasimolecular lasers made their appearance. Free electron lasers also appeared. The differences between free electron lasers and the lasers described above are very great--even to the point of some people not calling them lasers. However, in the area of short wave lengths producing high powers, it is the most promising.

The production and development of free electron lasers is closely related to particle accelerator technology (we will introduce particle accelerator technology later). The basic process associated with the production of free electron lasers is taking a beam of electrons and accelerating it to very high speeds. After that, it is made to penetrate a special magnetic field. This magnetic field is achieved by an arranged set of magnets positioned to alternate magnetic poles. When electrons penetrate the magnetic fields, they will go through pattern changes given rise to in magnetic field strength and direction. When electrons penetrate from the magnetic field of one magnet to the magnetic field of another magnet, the magnetic fields alter electron orbits, making electrons emit or absorb photons. If the magnetic field design is rational, light associated with electron beam emission will be more and absorbed light will be less. As far as appropriate placement of resonance cavity reflector mirrors is concerned, this will then produce free electron laser light (see Fig.4-9).

The U.S. Stanford University physicist Maidi (phonetic) first brought up this idea. In conjunction with that and going a step further, he experimentally verified it as well. In 1976, he amplified carbon dioxide laser light beams. The method was to/96 make incident light beams and free electron beams simultaneously pass through appropriate magnetic fields. In the second year, he demonstrated free electron lasers producing 3 and 4 micron laser beams. These two tests both used beams obtained on the twenty meter accelerator of the Stanford linear accelerator center for their execution.

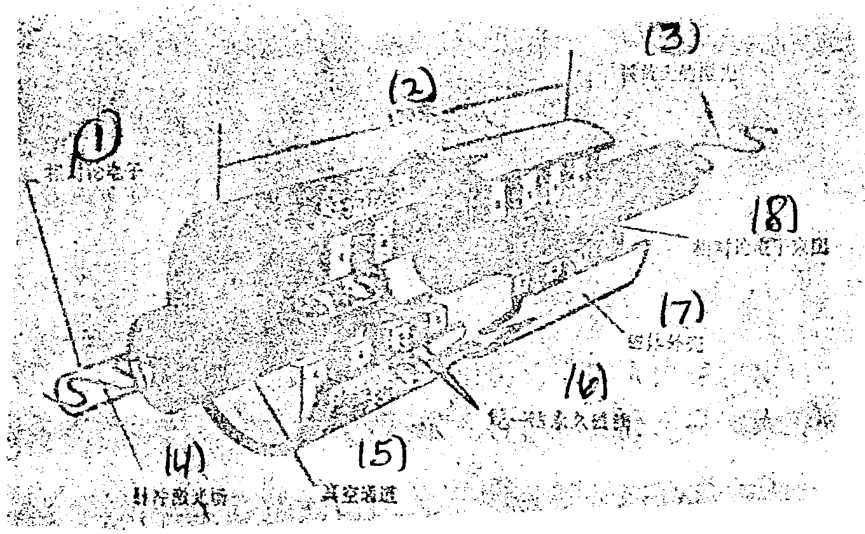

Fig.4-9 Free Electron Laser Structural Diagram. When electron beams produced by accelerators or storage rings (in the Fig. not [illegible] out) go through permanent magnet (illegible) following curved orbits, part of the energy is transferred to laser beams because this set of magnets is capable of making electrons, when passing through it, twist back and forth. Therefore, it is called "the twister (illegible)". Laser wave lengths depend on magnetic field spacial distributions and electron energies. Magnetic field spacial distributions have slight changes along beam paths. The purpose is to increase energy transformation rates.

Key: (1) Relativistic Electrons (2) (Illegible)
(3) (Illegible) Laser (4) Pulse Laser (Illegible)
(5) Vacuum Conduit (6) (Illegible) Permanent Magnets
(7) Solid Outer Shell (8) Relativistic Electron Beam (Illegible)

A number of other scientists spent many years and were only then capable of digesting the Maidi (phonetic) results. Theoretical research results were very plentiful. However, the results put out by theoretical physicists were still difficult for people outside the field to understand. This type of situation was nothing else than the kind satirized as the groping of blind people. However, speaking in terms of the Pentagon, the prospects for the utilization of this type of technology to produce high power lasers are very attractive. However, for many years, work to produce X ray lasers that are capable of operating has made no progress at all. The Defense

Advanced Research Planning Agency abandoned the X ray laser project, and will turn their attention to free electron lasers. After the appearance of theoretical articles, DARPA determined to carry out funding for the construction of high energy free /97 electron lasers. Experiments discussed above were carried out simultaneously at the Los Alamos national laboratory and TRW. The results of tests were satisfactory. Energies gotten from electrons were twenty times higher than the efficiencies reported by Maidi (phonetic) in his initial test reports. The person in charge of the Los Alamos free electron laser team was one of the people who created quasimolecular lasers. He said: "I have never encountered a match up between experimentation and theory as good as this."

When free electron lasers are used as high energy laser weapons, there are several advantages which are very attractive to people. Due to electron propagation in vacuums, as a result, turbulence problems associated with laser gases do not exist (in ordinary lasers, turbulence will destroy laser beam quality). Due to the fact that electrons are free, they are not bound to a certain specific atom or molecule. They do not have fixed transitions. As a result, it is possible to produce light in a very long wave length range from microwaves to ultraviolet. Of course, free electron lasers are not capable of operating in the entire wave length range. However, they are capable of using methods associated with the adjustment of magnet intervals and incident electron energies in order to change wave lengths of emission. Theoretical physicists predict that: using methods associated with electron beam reinforcement energies from continuous passage through magnetic fields, even if one takes electric power source losses, which have not been figured in in other lasers, and also calculates them in, overall free electron laser efficiencies are still capable of reaching 20%. High powers and short wave lengths associated with free electron lasers make their use as space laser weapons extremely attractive.

Free electron laser research personnel have gotten large benefits and prestige from currently existing accelerator technology. At the moment, they are all borrowing the use of other peoples accelerators. Once construction is begun on their own accelerator, they will derive benefits from technology developed during particle physics research over the past ten or twenty years. They believe that, in this way, it is possible to lower free electron laser building costs (at least economical as compared to other high power lasers). Moreover, it is easy to reach high powers. /98

There is a very big difference between the low powers which free electron lasers can currently reach in the experiments described above and the high powers of several million watts required for antimissile laser systems. Maidi (phonetic) estimates that, opting for the use of current accelerator technology, free electron laser powers are capable of reaching around 100 thousand watts. Scientists universally feel optimistic about increasing powers. However, it is very clear that this is something that will take several years.

Despite the fact that there is a great deal of optimism, free electron lasers which give people hope still have a number of problems--for example, capabilities for high power and high efficiency still have not been verified. Optical components to produce high energy ultraviolet light as well as being capable of withstanding ultraviolet light have still not been realized in any case. Accelerator technology is excessively complicated. Accelerators are too enormous. The first tests Maidi (phonetic) made were using a twenty meter long linear accelerator. To put it mildly, placing this kind of monster into outer space orbit is very difficult. When hearing gas kinetic laser developers call gas kinetic laser systems "ten ton wristwatches", another laser physicist attending a Masheng (phonetic) science and engineering institute discussion meeting stood up and asked whether or not

free electron lasers in space were a "thousand ton TV picture tube". This line brought down the house.

The problem of accelerator bulkiness is one of the important reasons that spurred the Pentagon to first consider using orbital reflection of ground laser beams. Besides the problem of not being able to take free electron lasers and put them in outer space, in a good number of areas, free electron lasers, in all cases, relatively ideally resolved long standing problems in the development of lasers. Free electron lasers are capable of freely selecting wave lengths and are not restricted by unique wave length characteristics of operating media. This then makes it possible to avoid those wave lengths which are severely absorbed by the atmosphere. If lasers are located on the ground, they can utilize ground electric power sources, and it is not necessary to wait for the establishment of nuclear power stations in space. Of course, this type of "delicate" ten ton TV picture tube will then not leave the ground and be sent into outer space where maintenance personnel cannot get to it. /99

4-14 Other High Power Lasers

In the past several decades, a number of other methods for producing high power lasers have also sparked peoples attention. Despite the fact that the two types of nuclear stimulation and solar stimulation lasers have not yet received serious attention, they are, however, still worth bringing up briefly.

The basic idea associated with nuclear stimulation lasers is to take energy produced by nuclear reactions and transfer it directly into obtaining particle number reversal. The key objective is to set up a small scale nuclear reactor pile. The core of the pile does not resemble that kind of solid rod normally used in nuclear power stations. By contrast, it uses a

gas pile core. The gas pile core of the reactor simultaneously also acts as laser operating medium.

Through several years of efforts, at the end of 1974, Sangdiya (phonetic) national laboratory and Los Alamos national laboratory, respectively, and, at almost the same time, demonstrated nuclear stimulated lasers. The person in charge at Sangdiya (phonetic) said that experimental results from their small team clearly showed that it was possible to take half the energy produced in fission and turn it into laser output despite the fact that their observed efficiencies were still far, far below this level.

The pity is that this idea will be difficult to realize. NASA, which early on initiated the execution of nuclear stimulated laser research, had no choice but to stop this project after reaching laser powers of 1000 watts. The reason was that it required having a specialized reactor pile and only then was it able to increase powers (see Fig.4-10). Moreover, the construction cost of this type of reactor pile exceeded the NASA budget. As far as research and development people associated with laser weapons were concerned, they had not expressed any great interest in nuclear stimulated lasers. They believed that shielding the reactor pile so as not to make casualties of friendly forces and control equipment would offset the advantages. A good number of observers also expressed doubts about the prospects of nuclear stimulated lasers. Because there was no objective, there was really no target to shoot at.

NASA actively considered another type of possibility. That was to use sunlight to directly or indirectly stimulate lasers. The long term objectives of both this type of laser and nuclear stimulated lasers did not lay in the weapons area but were to use as high power laser propulsion on space ships or directed power radiation from one point to another, as well as in situations

with applications needing higher powers than laser weapons and even greater energies.

Despite the fact that these methods lack theoretical estimates up to the present time, laser developers, however, will not simply stop here. Moreover, the Pentagon, right along, has also been looking for a new method to obtain high power lasers. Up to the present time, they are still far from being able to demonstrate any ideal laser weapons--that is, easy to operate, high efficiency, light weight lasers emitting strong powers at appropriate wave lengths. Even if all the latent capabilities possessed by currently available lasers were throw into realization, it would still require opting for the use of multiple types of paths. Only then would it be possible to make lasers act "quite well" in weapons applications. The difficulties associated with building a weapons system certainly do not lie entirely in weapons. Even if a large model laser cannon is built, (illegible) still must find a type of method in order to make it hit the target. The latter is an even more complicated problem than building a large model laser. /101

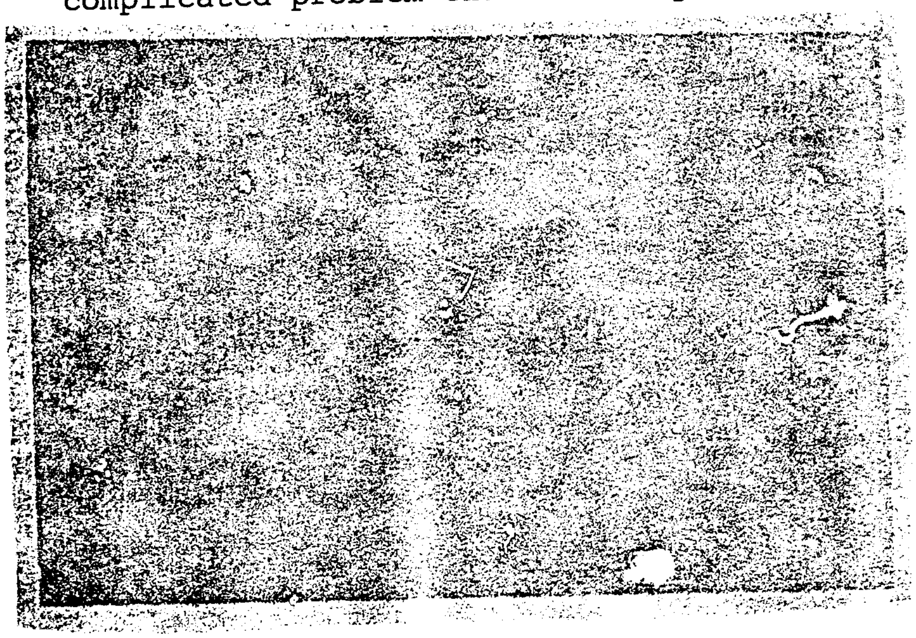

Fig.4-10 SP-100 Space Propulsion Nuclear Reactor Pile. This is also nothing else than a schematic diagram of a nuclear driven electric generator in space. The power is close to 100 thousand watts. The reactor pile is in the lower left of the Fig. The vanes extending back from the reactor pile are radiators.

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Chapter V CONTROL AND INITIATION SYSTEMS OF BEAMS

As far as an effective beam weapon is concerned, besides having a beam generator system capable of providing particle beams and laser beams, one should also have a number of even more key types of equipment. These are none other than systems associated with functions such as (illegible) tracking, beam control, as well as firing ignition, and so on. Beam weapons (illegible) a gun using particle beams or light beams as "bullets". However, this "gun" is unusually complicated. Its various parts are all high technology products. Moreover, it requires that the various parts be capable of high degrees of harmonization and coordination.

In order to be able to destroy distant targets, beams must propagate very long distances. In conjunction with that, they must concentrate very high powers in very small areas. In order to guarantee being able to discover targets, track targets, and, in conjunction with that, be able to carry out firing for adequately long periods on easily damaged points, it is also necessary to deploy a target homing and discrimination system as well as a target tracking system. Besides this, beam weapons also require an initiation system. Its function lies in discovering targets. In conjunction with that, after finding easily damaged locations on the target, "giving orders" to fire. After firing, it must also be possible to adequately discriminate targets which have and have not already been destroyed.

Beam weapons are a huge system. Speaking in concrete terms, beam generator systems are nothing else than lasers, microwave generators, and particle accelerator systems. These are merely relatively simple parts of it. Building a system which produces beams is relatively easy. However, if one wishes to make a weapons system which possesses the capability to discover,

discriminate, and track targets, and, in conjunction with that, destroy them, that, by contrast, is quite difficult.

Taking beam producing systems and turning them into weapons will run into a number of problems which are difficult to predict--for example, in the early 1970's, at a military base in New Mexico, the U.S. Air Force (illegible) carried out high power laser weapons tests. In the close vicinity of the (illegible) field, there was a stand of scorched (illegible) trees. This was nothing else than one produced at that time by out of control beams when weapons tests were carried out. /103

Beam weapons which take particle beams and laser beams and transmit them to easily damaged spots on targets are an extremely complicated operation. Taking laser weapons as an example, if one wishes to reach this target body, there are requirements in the several areas which follow:

(I) Identify true and false targets and discriminate easily damaged spots on target bodies.

(II) Track the target and make preparations in order to hit the target.

(III) Take the weapon beam and aim it toward an easily damaged spot on the target. In conjunction with this, follow it closely.

(IV) As far as beam focusing is concerned, make it reach the required beam strengths on the target.

(V) With regard to compensating for atmospheric effects, this makes beams not cause deviation off targets or lead to energy dispersion.

(VI) During the attack, maintain beam focusing.

(VII) In order to guarantee energies in beams, build up as much as possible on the target. In conjunction with this, avoid beam reflection by the target.

(VIII) Confirm that the target has already been destroyed.

The requirements set out above are extremely harsh. Among them, there are a number that are highly difficult to realize technically. At the present time, military research personnel are bending their efforts to achieve these requirements.

Requirements in these several areas can be divided roughly into two types. One type pertains to beam control. It includes beam direction control, beam focusing, as well as compensation for atmospheric distortions carried by beams, and so on. The other type, by contrast, pertains to initiation control. Initiation control primarily refers to the two areas of weapon aiming and initiation. Speaking in concrete terms, it includes discriminating and tracking target objects (supplying needed beam control information in order to facilitate determining direction); the picking out of easily damaged spots on targets; weapon firing; terminating fire after guaranteeing that the target has been destroyed, and several such areas (see Fig.5-1).

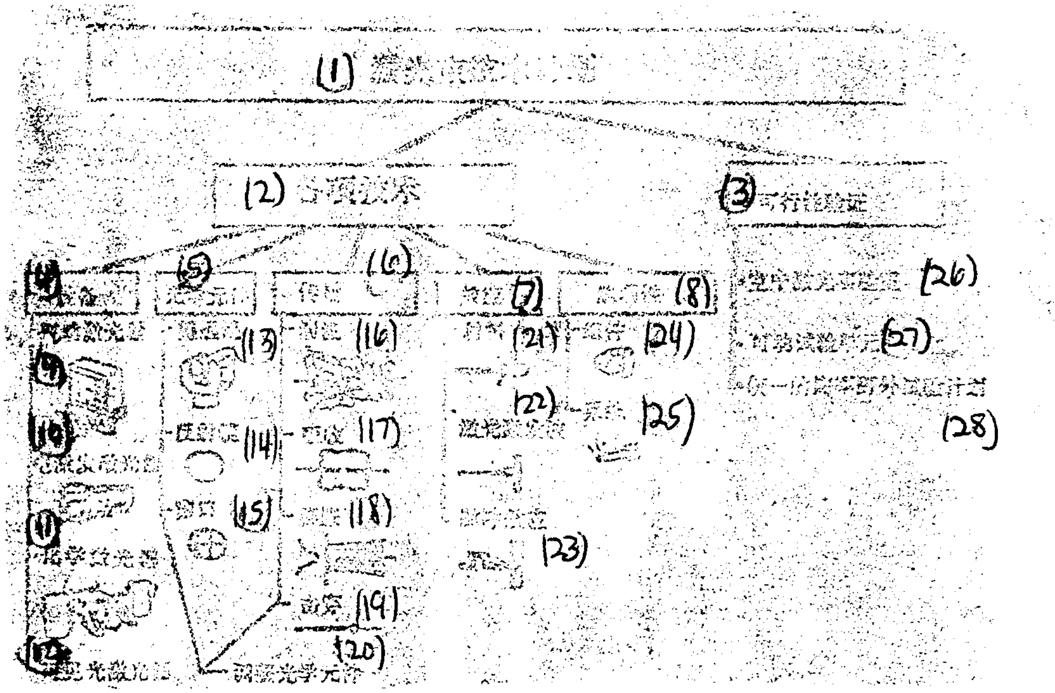

Fig.5-1 The scale of Pentagon high power laser weapon projects already far, far exceeds large model laser test (illegible) capacities (in the Fig., [illegible] there is a line "equipment"). Large model laser construction includes such test equipment as that related to laser (illegible) beam focusing components, (illegible), laser effects and target weakness, and so on. On the right side is a series of projects whose feasibility has already been empirically demonstrated and in which part of the projects are already completed. One part is in the midst of testing.

Key: (1) Laser Beam Technology Projects (2) Various Types of Technologies (3) Empirical Verification of Feasibility
(4) Equipment (5) Optical Components (6) Transmission
(7) Effects (illegible) (8) Weaknesses (illegible) (9) Gas Kinetic Lasers (10) Electrically Stimulated Lasers
(11) Chemical Lasers (12) Visible Light Lasers
(13) Telescopes (14) Reflector Mirrors (15) Windows
(16) (illegible) (17) Absorption (18) Expansion
(19) Penetration (20) (illegible) Optical Components
(21) Materials (22) Laser Wave Emission (23) Pulse Effects
(24) Subassemblies (25) Systems (26) Space Laser Test (illegible) (27) Mobile Test Units (28) (illegible) Test Project

Beam control is a technology peculiar to directed energy weapons. However, initiation control is military technology universally utilized in a number of weapons systems. The initiation control means required in directed energy weapons are much stricter than the initiation control means adopted in other weapons systems. According to the analysis of a number of observers, beam control and initiation control are much more difficult problems than building large power lasers. The reality is indeed this way.

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5-1 The Role of Beam Weapons

The different missions of beam weapons have different requirements for the beam control and initiation control systems. Beam weapon utilization is primarily in the atmosphere and in outer space beyond the atmosphere. Besides this, there are also cases situated between the two types--for example, taking lasers, placing them on the ground, and taking laser beams from the ground and sending them into space belongs to this kind of situation. In addition, it is also possible to take laser systems and a number of modern weapons systems and coordinate their use. At this time, laser systems are not a weapons system utilized alone. They do not require firing control systems. Moreover, beam controls are also much simpler. Taking a low energy laser and coordinating its utilization with initiation systems used on modern missiles, low energy lasers produce a light spot on targets, and sensors attached to missiles or bombs are capable of probing for the light spots and flying toward the target. As a result, this very, very greatly increases missile hit probability. Low energy lasers are also capable of measuring distance to targets, assisting artillery soldiers in firing tactics. The role of this type of low energy laser militarily is already widely known. However, it cannot be utilized to act as a beam weapon. This is all we will introduce here.

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Below, we make a rough introduction to the utilization of beam weapons. Directed energy weapons which are generally used in the atmosphere all have tactical missions on or off the battlefield. These weapons are capable of exerting their power for a few kilometers distance. In actuality, beams are transmitted at or near the speed of light. They are then capable of reaching targets almost instantaneously. Due to the fact that, when propagated in the atmosphere, beams will produce orbital distortions due to the influence of the atmosphere even to the point of disrupting them, as a result, there is a need for a complicated compensation technology to take beams and concentrate them on certain specified places associated with target objects. In the atmosphere, the beam weapons which are used are based on the different requirements on them from differences in the targets they are attacking. In most cases, there must be an extremely rapid response. As in the case when a warship is defending against a cruise missile, it is necessary, within an extremely short period, to destroy it before the enemy shell or missile has arrived. However, in the case of targets such as helicopters associated with slow destruction speeds, rapid reactions are then not very crucial. In a number of /106 cases, if enemy targets which one wants to destroy are mixed together with friendly forces, at this time, beam weapons must not only respond quickly, but they must also focus very well and operate accurately without errors.

If one wishes to destroy target objects, it is necessary to concentrate adequately high powers at points to be damaged on the target, making it sustain physical destruction. However, in certain cases, by contrast, it is only necessary to create functional destruction, and that is enough. If one uses very low powers to make target object sensors malfunction, one has then also reached the objective.

With regard to ground antisatellite weapons and space based antisatellite weapons, there are completely different requirements. These are determined by the orbit of the target satellite. The required weapons ranges are a few hundred to a few thousand kilometers. If one wants to destroy satellite sensors or make their easily damaged tracking systems and electronic circuits malfunction, then, medium power laser beams are adequate. This is an effective means of destroying the general run of satellites. If one wants to fire beams at a satellite to attack it from the ground, it is then necessary to make a number of compensations for the effects of the atmosphere.

With regard to a beam weapon system used to defend against nuclear weapons attacks, there are special requirements. During an all out attack, several hundred targets (for example, nuclear missiles) can appear at the same time outside a few thousand kilometers. Weapons systems must have rapid response capabilities if one is to destroy them within the shortest possible time before the missiles explode. On the basis of tentative plans from certain people, X ray lasers are capable of instantaneously and simultaneously destroying a good number of targets. However, other weapons systems are only capable of destroying targets one at a time. As a result, using X ray lasers, it is possible to destroy most nuclear warhead during an offensive. The remaining warheads can be dealt with by other beam weapons systems.

If laser weapons are placed in space, then, it is not necessary to be concerned about atmospheric effects. If they are placed on the ground, beams must be transmitted through a space "combat reflector". At this time, compensations associated with atmospheric effects can be realized through optical components on lasers. They can also be realized through "reflectors" in space. Together they form the weapon's beam control system. /107

A number of properties associated with beam weapons themselves will influence beam control systems. If one opts for the use of a certain type among visible light, ultraviolet light, X rays, microwaves, and charged particles, the technologies required are different. However, at this time, beam weapon initiation systems are still relatively similar. This chapter primarily introduces beam control and initiation control associated with high power lasers.

5-2 Role of Wave Lengths in Beam Adjustment

When wave lengths associated with laser operations are different, with regard to optical systems they utilize, they should also have different requirements. Based on the Fulanghefei (phonetic) diffraction principle, at a given optical system output aperture diameter, different wave lengths of output light have different faculae sizes. If one uses emission angles to measure sizes of light faculae, then, this emission angle has the relationship below between output system diameter D and light wave length λ :

$$\theta = 1.22 \frac{\lambda}{D}$$

Normally, the diameters of light beams put out from optical systems are very small. Moreover, emission angles θ are also very small--generally, microradians to milliradians. The diameters of faculae points which laser beams fire onto targets are the product of transmission distance and θ . It is also possible to use the size of divergence angles in order to describe the size of faculae points. In this way, the sizes of divergence angles θ are also nothing else than the size of faculae points using angles as units (see Fig.5-2).

The size of laser beam faculae points on targets are very important. Sizes of faculae points fired onto targets by laser beams of a given output power are different. The level of destruction produced is then different. It is possible to explain this because target damage level parameters are not powers but power densities or energy densities, that is, the magnitudes of powers on unit areas. They are gotten by dividing laser powers or energies by the areas of faculae points on targets. Another important factor influencing target damage levels is beam drift and undulation. That is also nothing else than--when destroying targets--requiring beams to be precisely fixed on the same faculae point in order to make lasers accumulate lethal doses on targets. Otherwise, beams will frequently drift. The result /108 is that the accumulated energies associated with any one point will not cause lethal damage to targets in any case.

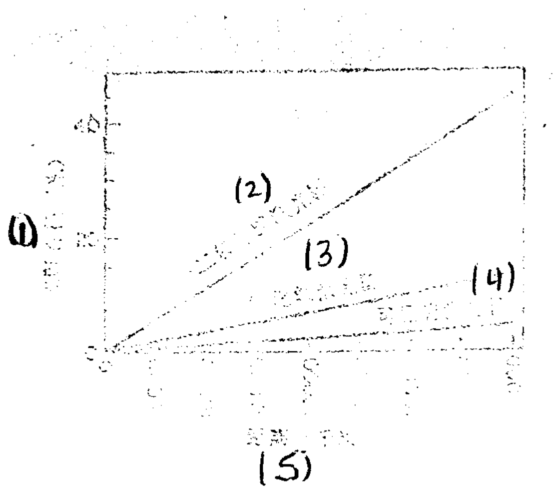

Fig.5-2 Magnitudes of Light Faculae Produced by a 30 Meter Diameter Laser Output Reflector at Different Ranges and Wave Lengths. Diameters associated with 10.6 micron carbon dioxide lasers, 2.8 micron hydrogen fluoride lasers, 0.5 micron visible light lasers, as well as (illeg.) relfector mirrors all (illegible) to laser wave lengths of 1/30. In the Fig., the curves represent the relationships between (illegible) associated with wave lengths of the three types of lasers described above and light faculae diameters.

Key: (1) Light Faculae Diameter (Meters) (2) Carbon Dioxide Laser (3) Hydrogen Fluoride Laser (4) Visible Light Laser (5) Distance (km)

On the basis of target lethal power densities or energy densities and maximum ranges, it is then possible to put forward requirements for beam weapons systems. If--in defending against missiles--it is necessary to take laser light with a power of 5 megawatts and focus it on an area with a diameter of 1 meter, then, the power density must at least exceed 6 megawatts/cm^2. If the target distance is 5000km, then, the divergence angle is required to be smaller than 0.2 microradians. If the lasers are hydrogen fluoride chemical lasers, output light wave lengths are 2.8 microns. Then, the output reflector diameter should be 17 meters. At the present time, mankind is still not able to manufacture such a large reflector. The largest telescope in the U.S. is installed in the Mt. Palomar observatory. Its diameter is only 5 meters. Moreover, the largest telescope in the world is a Soviet telescope with a diameter of 6 meters. It is said that its operation is really bad. The largest reflector used in space is NASA's space telescope. The diameter is 2.4 meters.

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In order to obtain (illegible) power densities, when laser beam powers are high or wave lengths are short, it is possible to use relatively small mirrors. If one uses an oxygen--iodine chemical laser with a wave length of 1.3 microns to replace hydrogen fluoride chemical lasers, then, when mirrors with 3 meter diameters make laser beams shoot to targets 5000km away, it is then possible to produce faculae points with diameters of 1 meter.

Due to damage levels being determined by the product of power densities and irradiation times, that is, the magnitude of energy accumulated on unit areas of targets, therefore, when beam powers increase or light faculae areas diminish, power densities will then increase. In order to guarantee having the same power densities, in cases where laser densities increase, it is possible to allow light faculae areas to be somewhat larger. That is also nothing else than making it possible for mirrors to

be somewhat smaller. Besides that, when it is required to have the same power densities, if light wave lengths are reduced, then, it is possible to make mirror dimensions smaller. Moreover, using methods associated with reduced light wave lengths, it is possible to even more effectively reduce the size of reflecting mirrors. With regard to the 5 megawatt power lasers described before, when powers are raised to 10 megawatts, faculae areas are allowed to increase to 2 square meters. Light faculae diameters are allowed to increase 1.4 times. Mirror diameters are allowed to shrink 0.715 fold. At this time, 17 meter reflectors are capable of shrinking to 12 meters. When power is increased 1 fold, mirror diameter reductions do not reach 1/2 fold. However, when wave length reductions are 1/2 fold, mirror diameters are then capable of shrinking 1/2 fold.

Manufacturing large mirrors is an extremely difficult business. In order to make large mirrors light weight, mirror surfaces must be thin. However, in order to prevent mirror deformations, mirror surface mechanical strength still must also be very good. Small mirrors are not only easy to manufacture. Moreover, their utilization is also convenient. If laser weapons are used to carry out antimissile, antisatellite tactics, then, there is a need to place in space a large surfaced mirror in order to receive laser beams from ground lasers. Wanting to take a large mirror and send it into orbit is quite difficult. This is precisely one of the reasons the U.S. Defense Department is particularly interested in developing short wave lasers.

No matter whether lasers are placed on the ground or in space, so long as light wave lengths are the same, they transmit the same kind of powers to faculae of the same size. Mirror sizes are just the same. Corning Glass Company, Perk-Elmer Company, Iterk Company, and Eastman Kodak Company have already planned to manufacture a reflector mirror with a diameter of 4 meters. The U.S. combined technology research center suggested

manufacturing a light weight mirror with a 10 meter diameter. The mirror body uses carbon fiber strengthened glass as /110 substrate. On it is plated a layer of silicon to act as reflecting film. According to 1981 reports, they set a fixed price of 87 million 5 hundred thousand U.S. dollars to provide this type of mirror. After Defense Department approval, it was completed within five years.

These two types of reflector mirrors are both unsuited to space shuttle propulsion. The diameter of NASA's space telescope is 2.4 meters. This already reaches the propulsion limits of the space shuttle. Taking a large mirror and propelling it into outer space orbit requires a high power rocket in order to launch it. In conjunction with that, it requires carrying out installation in space. This mirror can also first be pressed into the space shuttle cargo bay, and, after that, redeployed in space (see Fig.5-3).

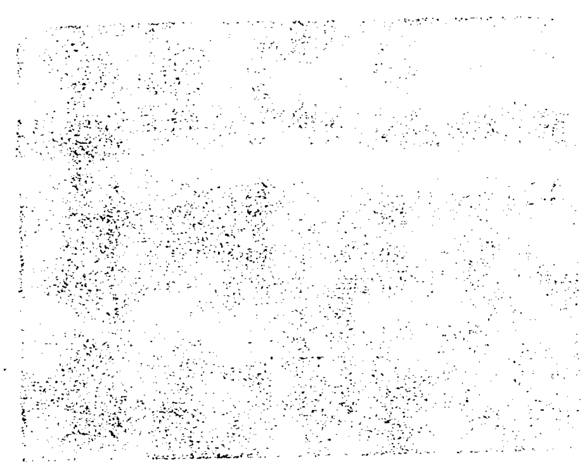

Fig.5-3 Installation in Space of a 30 Meter Diameter Reflecting Mirror. It is capable of taking laser light and reflecting it to space craft in order to supply a power source, in conjunction with that, driving space craft flight.

Problems actually encountered are unusually numerous. Despite this, the Pentagon and the U.S. space industry still drew up large scale plans. At the present time, there is a plan to manufacture a mirror with a diameter of 30 meters. The U.S. space agency plans to use laser propelled space ships and opts

for the use of laser beams in order to transmit power. Manufacturing this type of huge mirror is a large and difficult process. The path for manufacturing this type of mirror has three branches: one is to develop structures which can be expanded in space; the second is designs capable of altering the form of the mirror, taking compact forms for launch. After that, they allow it to open up--for example, opting for the use of methods associated with memory alloy materials, and so on. The third type of method is taking mirror components and launching them up, reassembling them when they reach space. Looked at in technical terms, this type of method is relatively practical. Mirror surfaces can use glass or ceramic materials. When temperatures change, these types of materials require that their sizes and shapes almost do not vary. Using graphite--epoxy in order to manufacture the mirror frame, the thermal stability properties can be matched to the mirror.

When laser weapons point toward targets on the ground, the sea, or in the air, target distances are not far. Generally, they are within ten or twenty kilometers. At this time, laser output mirrors are not a very severe problem. On targets 20 kilometers distant, the power densities on faculae points are 62500 times those at 5000km. If one wants to reach the same power densities as at 5000km, then, the diameters of mirrors required by 2.8 micron hydrogen fluoride chemical lasers are adequate at 6.3cm. At this time, mirror diameters are reduced to within one percent of the original diameter (17m). If one uses methods associated with a direct ratio between mirror weight and mirror surface area to estimate, then, mirror weights can be reduced to 1.6×10^{-5} times the original weight (two parts in 100 thousand).

In fact, mirrors required by lasers used at close distances must be a little larger than this. The most important single reason is that lasers will harm mirrors. If mirrors are very

small, then, powers on unit areas of mirror surface are larger than power densities on targets. Moreover, mirror reflectivities do not reach 100 percent. In this way, mirrors are bound to absorb a portion of the light. When mirror surface power densities are very high, long periods of operation will lead to damaging of the mirrors themselves (Laser reflectors used in space will be much larger than faculae points on targets. As a result, these kinds of problems do not exist.) If one takes mirror diameters and enlarges them somewhat, it is not only possible to make focusing properties good. But, one also increases the safety of the mirror itself. Enlarged mirror diameters are one way of raising mirror safety characteristics. Secondly, they can also be used as methods to resolve the raising of mirror surface reflectivities and mirror surface cooling.

Besides bulkiness and difficulties launching them into orbit, large model reflector mirrors are also very difficult in manufacturing processes. If one wishes to guarantee reflector mirrors having good optical properties, working requirements are very strict. Speaking in terms of tolerances, they must be smaller than one tenth or one twentieth the laser wave length. With regard to 2.8 micron hydrogen fluoride chemical lasers, it is required that variations between the worked mirror surface and the ideal mirror surface be smaller than a few tenths of a micron. When wave lengths are shorter, mirror surface requirements are even harsher. For many years, following along with the development of precision optical component working technology, people have already been enabled to achieve requirements associated with this type of deviation. However, if one wishes to also achieve this sort of requirement during the working of components with very large dimensions--no matter whether it is in regard to manufacturing or installation--there are very great difficulties in all cases. Moreover, very small temperature differences are then capable of leading to very large distortions.

This is a simple mechanical problem of maintaining high precision over large areas. It is also possible to say that it is a question of maintaining the same conditions everywhere on large objects.

The mirrors which are the most able to withstand high power laser irradiation are made from metal. They generally are honeycomb types. There are holes in them letting coolant flow in. The U.S. Defense Department has already spent several million U.S. dollars to set up methods for manufacturing that type which absorbs less than 1% of incident laser light. Moreover, they are mirrors which are capable of very quickly using conduction methods to conduct away absorbed heat energy.

Due to the fact that, within the U.S. Defense Department, there is a devotion to the developing of strategic technologies, high power laser reflector mirrors occupy a notable position. As a result, when U.S. government officials learned that a small company in Keluona (phonetic) California--the Sibaoer (phonetic) optical research company--took a metal mirror capable of withstanding high power laser light and sold it to the Soviet Union through their agents in West Germany, they were very uneasy. When the government attacked this company and its general manager, Walter Sibaoer (phonetic), Sibaoer (phonetic) defended himself saying similar technologies are universally utilized techniques. However, in the end, Sibaoer (phonetic) and his company were confirmed as having violated U.S. export control regulations. After this incident, the U.S. government began to implement regulations limiting export of sensitive technology. In 1980, the U.S. canceled a 134 million U.S. dollar contract to build a plant for the Soviet Union. This plant was for the production of tungsten carbide oil field drill rigs. However, the U.S., due to fears that the Soviet Union would take this type of powder metallurgy technology and use it for such military

purposes as armored weapons and laser reflector mirrors, canceled this contract.

5-3 Problems Confronted by Beams During Atmospheric Transmission

Ground based laser weapons must take beams and send them to targets. It is necessary to overcome orbital distortions given to beam transmissions by the air. The reasons distortions are produced are relatively complicated. There are many types of causes that play a role. Moreover, with respect to a number of factors, there is still no adequate understanding to the present day.

One important cause of beam distortions is turbulence effects. Due to the roles of factors such as wind, temperature gradients, transmitting objects, air flows, and so on, air densities never stop their random fluctuations. As a result, this leads to laser light beams giving rise to deviations. In clear and clean night air, star light scintillation, is nothing else than the same type of producing cause.

High power laser beams themselves are capable of leading to other problems. The most famous is "thermal diffusion". Causes producing this type of effect lie in that fact that, when laser beams penetrate the atmosphere--due to the fact that air is not an ideally transparent substance--there is always a portion of the laser light that is absorbed by the air. After the air absorbs laser light, the gases are heated, causing the gases to expand and densities to be reduced. As far as this type of low density hot gas is concerned, the refraction index is smaller than the refraction index of the surrounding cold air. In this way, laser paths then form a diverging lens, causing laser beams to diverge. This point can also be understood in this way: hot gases and normal density gases construct a light conducting

fiber. However, this light conducting fiber's aperture diameter is very small. As a result, transmission properties are very bad, leading to light beam divergence (see Fig.5-4).

When laser beams are transmitted in air, thermal diffusion becomes extremely complicated. Laser weapons track targets during movement. However, the air itself is not completely still. Laser light heating of air causes it to expand. Refraction indices of air after expansion become smaller. Light beams then deviate toward the rarefied hot air. In this way, when there are flow movements associated with the air or laser weapons motions, the directions of laser beams then give rise to deviations. When there is wind, the directions of light beam deviations are the directions with the wind. As far as focus spots produced by beam direction distortions are concerned, they are narrow perpendicular to the direction of the wind. Parallel to the wind direction, they are wide.

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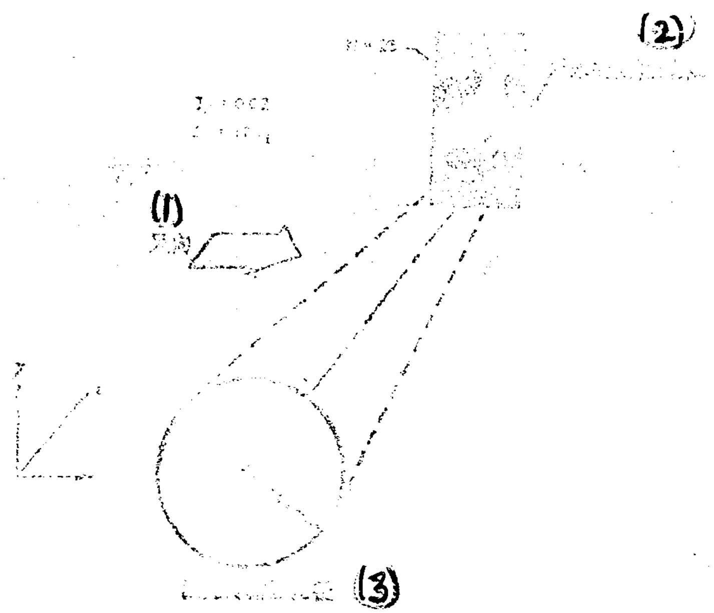

Fig.5-4 Air flow movements cause continuous laser beams to give rise to thermal expansion effects. If there is no air in the laser's path, then laser beams are capable of (illegible) focusing within the periphery of a very small circle on the target. This is called positive beam diffusion. Thermal

diffusion and gas flows work together. It is possible to make beams diffuse. Tracks curve causing laser beams on targets (illegible) a very large area--for example, the white portion in the Fig. The data in the Fig. was obtained with reference to laboratory (illegible) tests.

Key: (1) Wind Direction (2) Undistorted Target Surface (illegible) (3) Laser Transmission (illegible) Aperture

The transmission of laser light in air involves complicated theoretical problems. In the U.S., with support from the military, physicists carried out a number of painstaking operations, trying to explain all the processes given rise to. They made a number of simple assumptions, and got results for beam transmission in the atmosphere. The work of a number of U.S. and Soviet physicists in this area has a considerable portion which directly serves directed energy weapons.

Weather conditions such as rain, snow, fog, clouds, and so on, have even greater influences on beam transmission. Rain drops or snow flakes are much larger than the wave length of light. They are capable of blocking the transmission of light. It is only at wave lengths such as those of microwaves that it is then relatively easy to penetrate dust, rain, and fog. /115

High energy laser beam heating effects are a help in overcoming a number of transmission problems related to weather. Carbon dioxide high energy lasers are capable of heating small water droplets in fog, making them evaporate and clearing out a path. Military personnel are capable of being aided by this type of method in eliminating fog and rain.

On the battlefield, besides bad weather, there are still more complicated cases. After small arms and artillery open fire, smoke and fog are produced. Tanks and vehicles put out smoke and oil plumes. Explosions cause dust as well as purposely

laid smoke to obscure vision. All such things are capable of blocking laser transmission.

Bad weather, dust, and smoke not only block laser beam transmission. They will also cause obscured vision and can cause infrared optical system malfunctions as well. At this time, relying on microwave radars, it is possible to discover targets. However, microwave radar resolution capabilities are very limited. They are not capable of probing out easily damaged points.

Due to thermal diffusion effects, when laser powers exceed a certain value, increasing their power, on the contrary, causes energy reaching targets to decrease. The reason is that thermal diffusion effects set off by lasers follow along with increases in laser power and very rapidly increase. The larger beam powers are, the higher are the percentage ratios of energy taken off target points. As a result, besides space based laser weapons, laser weapons operating in the atmosphere are certainly not more effective the greater their powers are.

5-4 Resolving Problems Existing in Transmission

Speaking in terms of basic principles, adjusted laser output characteristics can reduce certain transmission problems. For example, using pulse beam operating types to replace continuous beam operating types, it is then possible to reduce thermal diffusion. The reason is that air that has been heated by lasers becoming rarefied always requires a certain period. Air density changes are a type of sound wave which propagates at the speed of sound. The time periods associated with air being heated and becoming rarefied are on the order of microseconds. Before pulse beams produce diverging lens effects in sound waves and then stop, beam divergence will at once very, very greatly diminish.

It is certainly not taking very large energies and focusing them in ultra short pulses which will be capable of resolving problems. Extreme shortness of pulses will produce a number of other problems. For example, electrons stripped off from gases will cause gas ionization. Moreover, following gas ionization, gases will severely absorb light and block beam transmission. Strong pulses are capable of very strong ionization effects, as a result, producing a lightning type light path.

Due to problems encountered with continuous beams and ultra short pulses, selecting appropriate operating forms is already extremely urgent. When using a series of short pulses, the energy that it carries must be the same as the output situation for a continuous beam. Moreover, the sustainment period for each pulse should be sufficiently short so as to avoid thermal diffusion. However, the interval between pulses must be suitably long in order to guarantee that the heat produced by a pulse is consumed within the (illegible) of the following period and does not lead to the production of influences on the next pulse. Optimum pulse repetition frequencies depend on beam size, relative motion of beam and air, as well as how much energy each pulse absorbs.

Energy distributions inside laser beams will influence the role of thermal diffusion. Speaking in terms of the technical terminology of physics, the distribution states of energy within cross sections of laser beams are nothing else than cross section distributions of laser light. Different cross sectional distributions have different thermal diffusion effects. The most commonly seen cross section distribution is the base state cross sectional distribution. In this case, laser beam energy is concentrated at the center of the beam. At this time, thermal diffusion effects will be aggravated. If one selects for use other cross sectional distributions--for example, taking energy

and concentrating it in a ring at the edges of the beam, it is then possible to reduce the role of thermal diffusion.

Taking beam areas and enlarging them, powers are maintained invariable, that is, reduced power densities are capable of reducing the effects of thermal diffusion. However, this must be connected with the manufacture of reflector mirrors.

5-5 Adjustable Optical Systems

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Above, we analyzed problems existing in laser beam transmission. Moreover, we presented a number of compromise solutions. However, the optimum method for handling these problems is, by contrast, optical calibration, that is, through optical systems, adjusting laser light wave fronts. Wave front forms after adjustment are capable of compensating for distortions produced when beams penetrate the atmosphere (see Fig.5-5).

The lens of the human eye is an adjustable lens which is capable of producing deformations. It is a natural advanced optical system. Moreover, artificially manufactured optical systems have no way of comparing their functions to the human eye. Due to the fact that the materials needed to manufacture optical lenses are all rigid, as a result, the normal optical system is certainly not capable of adjusting wave fronts in accordance with requirements. At the present time, there is one type of very promising solution. This is nothing else than a type of mirror which is capable of changing the reflecting surface configuration. This type of mirror is called a "rubber" mirror (In actuality, it certainly does not include rubber. It simply borrows the name rubber for a stopper with soft, flexible properties). Roughly speaking, there are three types of /118
manufacturing methods:

(I) Use a number of small mirror pieces to put together into a large mirror. Each piece is mechanically adjusted by a drive system similar to a piston (Fig.5-6).

(II) Take a reflecting material and apply it onto a substrate of piezoelectric material. Use an arrangement of electrodes on the substrate to apply different voltages to different locations. When the sizes of the voltages applied are different, the shape adjustments of the substrate are also different. In this way, it is then possible to adjust the shape of the reflector surface on the basis of requirements.

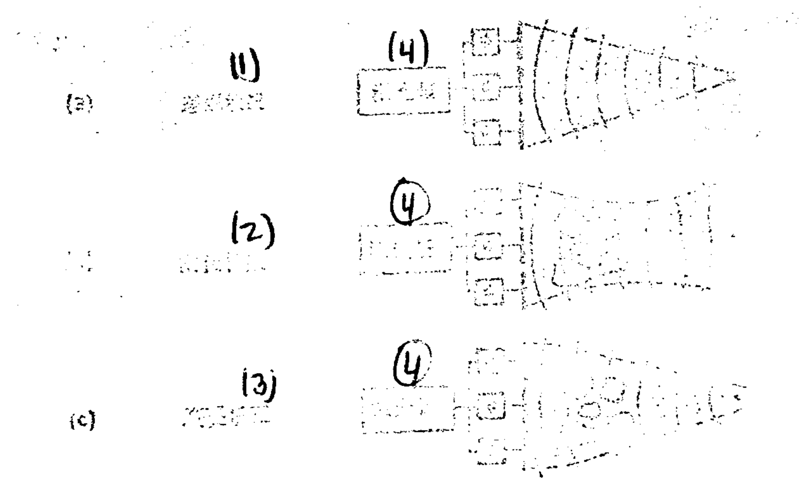

Fig.5-5 When lasers propagate in the atmosphere, there are problems--both, theoretically, how to overcome these problems and, in practical terms, the ability to focus a laser beam in a concentrated way on a very, very small point (Fig.a). In the atmosphere, due to turbulence, thermal diffusion, as well as the influences of other factors, it makes laser beams diffuse into very large areas (Fig.b). Using appropriate optical components, it is possible to (illegible) correct the light wave energies emitted from high power lasers, as a result, weakening the diffusion (Fig.c). In the Fig., Φ stands for the control system associated with laser light output reflecting mirrors. Output reflector mirrors are capable of controlling laser light (illegible). So long as--in the bottom Fig.--(illegible) control systems, only then is it possible to compensate for the effects of the atmosphere.

Key: (1) Ideal Configuration (2) Turbulence Diffusion (3) (Illegible) Correction (4) Laser

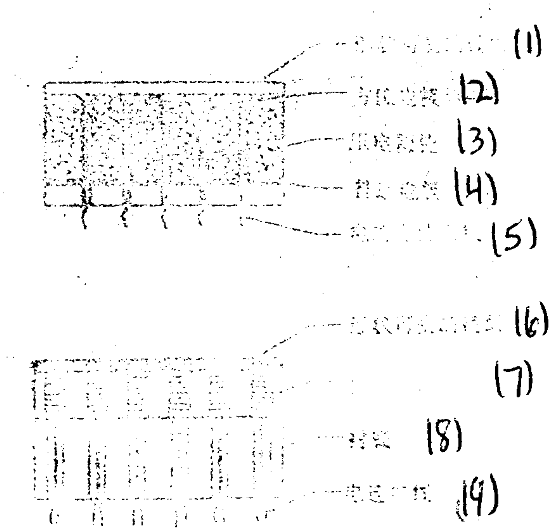

Fig.5-6 Cross Section Diagrams of Two Types of Driven Reflector Mirrors. As far as the upper reflector mirror is concerned, the variable shape mirror surface is covered with a large piece of piezoelectric ceramic. When there is voltage on the piezoelectric ceramic, the heights can change. When different voltages are applied to different locations on the piezoelectric ceramic of the reflector mirror, the height of the corresponding piezoelectric ceramic is then different. As a result, the shape of the reflector surface is made to give rise to irregular changes. In the case of the lower reflector mirror, the shape variable reflector surface covers an (illegible) adjusting device similar to a piston. They follow along with fluctuations in electrical signals, and, as a result, change the shape of the mirror surface.

Key: (1) Shape Variable Mirror Surface (2) Positional Electrode (3) Piezoelectric Ceramic (4) (illegible) Electrode (5) Electric Position Lead (6) Shape Variable Mirror Surface (7) Independent Adjustment Device (8) Base (9) Electrode (illegible) Connection Line

(III) Use a set of independent control mechanical systems to precisely and continuously adjust mirror surfaces. This time it is not the use of piezoelectric effects but the use of mechanical forces which change the shape of the mirror surface.

Requirements for reflector mirror optical surfaces are very strict. No matter whether it is adjustments to surface working or to surface shape, they generally must attain a precision which does not vary from the ideal case by more than one twentieth the wave length of the light waves. Mirror shapes must at least be able to adjust within a range of 4 wave lengths. Besides this, adjustments to frequencies must reach 1000 iterations per second to be appropriate to wave motions in the atmosphere. There is a direct relationship between laser device tolerances and laser light wave lengths. The shorter wave lengths are, the smaller the required tolerances.

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High power laser reflector mirrors must also be able to support high powers. Although reflector mirror reflection rates are very high, there is always a portion of light, however, absorbed by the mirror surface. When light beam powers are very high, absorption is quite large. In this way, mirror surfaces will then be made to generate heat--as a result, leading to shape distortions, even to the point of destruction. In connection with this, there is a need to install cooling systems in relfector bodies, allowing coolant to circulate through surfaces and lower temperatures. In this way, reflector mirrors become extremely bulky after the addition of adjustment systems and cooling systems. Their weight can even exceed 1 ton.

Good optical systems are not only capable of compensating for laser beam distortions caused by the atmosphere, but are also able to overcome beam divergence problems. When laser beams give rise to reactions due to air flows and air, they will put out energy. Therefore, turbulence during laser transmission

processes is unavoidable. If it is possible to adjust mirror surfaces, then, it is possible to take lasers and concentrate them on targets.

At the present time, in laser reflector mirrors developed by the U.S., the best openly announced systems are of the three types below: one has a diameter of 16cm, uses 37 adjustor devices, and has adjustment frequencies that reach 200 iterations/second with adjustment precision of 0.1 microns; another one still has a diameter of 16cm. However, it uses 69 adjustment devices and has an adjustment frequency which reaches 3000 iterations/second. There is still another one which has a diameter of 20cm. It uses 61 adjustor devices and has an adjustment frequency of 10000 iterations/second. Moreover, effective cooling is possible (see Fig.5-7).

During the manufacture of the most advanced several reflector mirrors described above, a number of difficulties were met with. There were only reflector mirrors which were certainly incapable of satisfying beam weapon requirements. The reason was that suitable optical systems are certainly not merely a reflector mirror. They must also have a suitable control system. First of all, this system must be able to precisely understand problems met with during beam transmission. As a result, it is necessary to equip it with probing equipment to collect this information. Secondly, on the basis of data collected, the effects produced must be deduced. However, deciding what type of compensating measures to adopt (illegible). At the present time, difficulties associated with this area are still quite a few. In theoretical terms, this is not yet mature. Besides this, there is a requirement for control systems to be able to rapidly adjust systems having fast feedback.

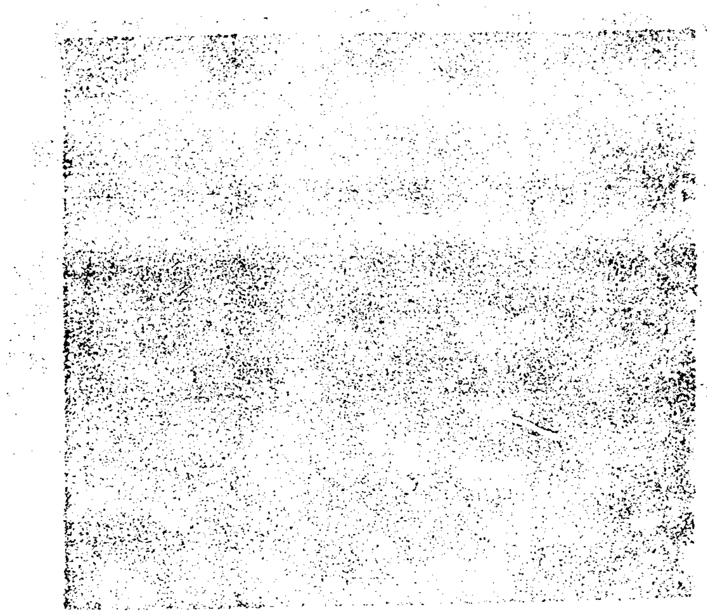

Fig.5-7 Cross Section Diagram of Variable Reflector Mirrors Manufactured by the Rocketdyne subsidiary of Rockwell International Company. This reflector mirror has installed 19 adjustor devices. Interior optical adjustment devices are very complicated. This reflector mirror radius is 40cm. The weight is 45kg.

5-6 Mutual Effects Between Beams and Targets

Laser weapons take well focused beams and fire them at targets. They are not necessarily then capable of exerting their effects. The reason is that the mutual effects of beams and target surfaces are a very complicated process. They strongly depend on beam properties and target characteristics.

Probably no one will believe that using laser beams to destroy targets definitely requires taking the substance of military targets and melting or vaporizing it. The purpose of emitting continuous laser beams lies in burning through target surfaces, making internal components sustain lethal damage. Actual damage processes vary with the target. It is possible for them to have many forms. For example, destroying warhead fuses

makes them unable to explode, or detonating fuses causes explosions ahead of time. It is also possible to punch holes in fuel tanks, causing explosions. It is also possible to destroy control systems or guidance systems, making missiles land very far from predetermined targets.

Laser weapons used to initiate offensives--besides requiring relatively high firing accuracies--should also be able to bite into targets, making laser beams have relatively long irradiation periods on targets. The length of this period is determined by laser powers and target properties. If target reflection capabilities are strong, within a fixed period, the accumulated energies on it will then be small. The needed irradiation time is then long. We will talk about this later. This type of reduced energy accumulation method is one type of counter measure. Pulse beams are relatively beneficial during offensives. They are not only capable of overcoming transmission problems in air discussed above. Moreover, very short pulses are capable of causing intense vaporization on target surfaces. They are also capable of producing a type of shock wave able to penetrate through targets, creating mechanical damage.

Fig.5-8 These instruments are used in experiments on such areas as aiming, stabilizing, and focusing laser beams in order to acquire experience in how to focus high power lasers in a precise direction.

The influences of target surface properties on the state of damage to targets under beam weapon attack are very great. In order to defend against enemy beam weapon attacks, military installation surfaces must have special requirements. To this end, military personnel are extremely interested in material surface properties.

5-7 Initiation Control

Initiation control is an essential system for such directed energy weapons as laser weapons, particle beam weapons, X ray lasers, and so on. The basic problems which initiation control resolves are observation, tracking, aiming at targets, and, subsequently, opening fire. In conjunction with this, there is final confirmation whether or not the target has already been destroyed. The U.S. Defense Department requirement with regard to initiation control is: "Laser weapon initiation control must possess special capabilities in order to confirm and determine, among myriad targets, which ones are dangerous targets. Besides this, they also need to be able to rapidly discriminate whether or not attacking targets have been destroyed in order to facilitate rapidly turning the attack to the next target."

Military systems at the present time must still rely on soldiers in order to aim at targets. In this way, when the enemy fires at them, they will let potential targets escape because of being shaken up and taking cover. In addition, soldiers on the battlefield generally only have the protection of steel helmets. As a result, it is easy to be attacked by multiple types of weapons. In comparison, beam weapon defense systems have a number of advantages. First of all, they will not miss the time to attack by delaying due to unexpected situations. Second, their reactions are fast. Moreover, they have a very high

discrimination capability and are capable of exerting their influence within a very large combat radius. Besides this, beam weapons fully actualize the advantages of high technology war. A number of military people believe that future soldiers will not always be a necessary part of military systems.

Beam weapons, in the process of exerting their effects, first of all, confirm targets. There are two normal types of methods for confirming targets. One type is the active form, that is, sending scanning signals out into space. On the basis of received returning information, targets are confirmed. This type is the same as the operation of a radar. However, the signals sent out can be microwaves, millimeter waves, visible light, or infrared light. Visible light and infrared light are capable of being produced by lasers. Returning signals must be analyzed and processed. Only then is it possible to determine target characteristics. Generally, each type of aircraft has a special radar signature. Following along with differences in aircraft direction and other conditions, this signature will also change. This type of situation explains returning signals being the key to confirming targets. There is also a passive method of confirming targets. Using a set of binoculars to sweep the heavens to find enemy aircraft is a method which belongs to this type. Modern methods of target confirmation use electronic systems to search for infrared radiation sources. In conjunction with this, they are (illegible) turned into recognizable images.

Active type and passive type target confirmation methods all require a step to interpret signals. In the past, this process was in the charge of very well trained operators. However, now, by contrast, it is possible to use computers in order to complete it. Their reaction time is very fast.

Only when there are initiation systems capable of confirming targets associated with weapons systems is it then possible to

put them to use. The reason is that weapons systems which are not capable of distinguishing friend and foe are quite dangerous. After targets are confirmed, they are then tracked. The process of beam weapons tracking targets has two steps. The first is rough tracking, observing the target, establishing the ballistic track, and moving large primary dishes to track it. Once the probable path is confirmed, systems will then go into precision tracking processes. Through rapid movements of a small, light mirror, easily damaged spots on targets are tracked. After optical systems aim, firing systems will initiate lasers. Moreover, beams are fixed on easily damaged spots for long periods of time, until targets are destroyed.

One crucial technology associated with contemporary tracking systems is laser radar. As far as the long utilized microwave radar is concerned, there are a number of people who think it has many drawbacks--for example, microwave wave lengths are relatively long, and radar resolution capabilities are bad. Besides this, a number of new model missiles are capable of tracking microwaves and destroying microwave antennas. If one uses laser weapons of very short wave length to replace microwaves, then, they are capable of making radar resolution capabilities greatly increase. In this area, the greatest progress has been made using infrared laser radars associated with carbon dioxide lasers. The U.S. Masheng (phonetic) science and engineering institute's Lincoln laboratory already set up this type of radar system in 1981.

Initiation control, after firing, still has a mission, that is, confirming whether or not targets have already been destroyed or lost their effectiveness. Only when targets are /124 confirmed as having lost their capability to re-exert their influence can beam weapons then be able to attack the next target.

Confirming whether or not targets have been destroyed must be carried out on the basis of the situation associated with the creation of the destruction. If beam weapons create enormous physical damage on targets--for example, fuel canister explosions or premature detonation of warheads--it is relatively easy to confirm. However, the degree of functional destruction of electronic equipment inside targets is difficult to confirm.

Initiation control systems should have very strong information processing capabilities. This requires the completion of an auxiliary information network composed of computers. Generally, laser weapons take a few seconds to fire once. With regard to particle beam weapons, by contrast, there is a requirement to fire several times each second. In time periods on the order of seconds, (illegible) tracking, aiming, and firing. Moreover, such environmental information as atmospheric conditions must be collected and then used in the operating configurations of fast moving adjustor systems. These also require computers in order to complete.

At the present time, a number of large technical difficulties still exist in association with beam weapon beam control and initiation control systems. There degree of difficulty is much greater than building high power lasers. This requires the development of a number of sciences and technologies in order to achieve relatively fast progress.

Chapter VI X RAY LASERS AND γ RAY LASERS

Beam weapons are a type of weapons system which uses particles or photons to take the place of "bullets". From discussions above, it is known that, when photons are used as bullets, the shorter photon wave lengths are (that is, the higher single photon energies are) the better weapons system properties such as beam directionality, focusing, and so on, then are. People very naturally think then of using the shorter wave lengths of X rays and even up to γ rays in order to complete this task. X ray lasers and γ ray lasers are not only long term objectives pursued by scientists. They are, moreover, also incomparably powerful weapons which are (illegible) desired by military people.

6-1 Difficulties Existing with X Ray Lasers

X rays, γ rays, and what is normally referred to as light, in essence, have no differences between them. They all are electromagnetic radiation. The wave lengths of visible light are 0.4 - 0.7 microns. X ray wave lengths are between 0.1 - 100Å. However, γ ray wave lengths, by contrast, are smaller than 0.01Å (1Å = 10^{-10} meters). Due to the fact that a certain frequency of light corresponds to a certain energy, looking from the quantum nature of light, the energies of visible light photons are in the range of a few electron volts. X ray photon energies are thousands of electron volts, and γ ray photon energies lie above mega electron volts. Since the natures of X rays, γ rays, and visible light are the same, in such a case, we are then able to use a form of amplification of stimulated radiation in order to produce X ray lasers and γ ray lasers. This type of idea, in principle, is correct. However, in reality, difficulties are very numerous. First of all, we know from the knowledge above

that lasers are produced by stimulated radiation. At the same time as stimulated radiation, there always exists spontaneous radiation. The probability ratio associated with the two determines the ease or difficulty of producing laser light. If the probability of stimulated radiation is large, and the probability of spontaneous radiation is small, then the process of producing laser light will be relatively easy. There is a relationship between the specific values of the probabilities of the two and the cube of the wave length emitted. The shorter the wave length is, the smaller the probability of stimulated emission, and the more difficult it is to produce laser light. Theoretical calculations make it clear that, when wave lengths are shorter than 0.01Å, laser amplification is then not possible. Secondly, X ray energies are very high. Visible light is electromagnetic radiation put out when outer shell electrons of atoms transition. However, X rays, by contrast, are electromagnetic radiation released when atom inner shell electrons transition. X ray lasers still require taking electrons and raising them to high energy states in order to produce particle number reversal. Moreover, one atom stimulated to a high energy state has a fixed life. Stimulated state lives are directly proportional to the square root of released ray wave lengths. X ray wave lengths are very short. The lives of corresponding high stimulation states are quite short. In this way, stimulated atoms, after excitement, will rapidly lose their stimulation down to a low energy level and send out X rays. Of course, most radiation is spontaneous radiation. This problem can be understood in this way: due to very short lives, excited atoms--before producing stimulated radiation--will then lose excitement by spontaneous radiation. In this way stimulated radiation will then be difficult to achieve. What is more important is that it is very difficult to create particle reversal. Lasers are not able to sustain operation. Once again, due to short lives of stimulated states, energies will also be very high. As a result, it is necessary to use very strong pump

powers within very short periods of time to stimulate X ray lasers. With regard to lasers with wave lengths of 1Å, each atom requires 2 watts of pump power. If there are 10^{-12} grams of carbon atoms operating at this wave length, the required pulse power is 10^{12} watts. Producing pump powers this strong is not an easy matter.

In addition, at the present time, there are still no reflector mirrors or resonance cavities capable of providing X ray stimulation to utilize. When X rays are fired into material, quite a large portion is absorbed. There is only one small portion which is reflected. Reflection rates of reflector mirrors manufactured using film interference principles are also not high--only 50-60%. With regard to X ray lasers, difficulties not only exist in association with not having reflector mirrors and resonance cavities. There is another severe problem, that is, X rays with very high powers are easily absorbed by material.

As a result, this will cause operating medium evaporation. /127

6-2 X Ray Laser Production Methods

X ray lasers are unfavorable for the use of resonance cavities. They and the "pulse" operating processes in cosmic interstellar space gas clouds are the same. When spontaneously radiated photons pass through material, they will then initiate the emission of other photons. If there is no reflection associated with reflector mirrors, the direction of photons will then not be altered, and they will fly along a straight line. Laser operating media generally are made from very long fibers or cylinder shapes. In this direction, laser light is able to achieve strong amplification. Laser beam direction is determined by the direction of the fibers themselves.

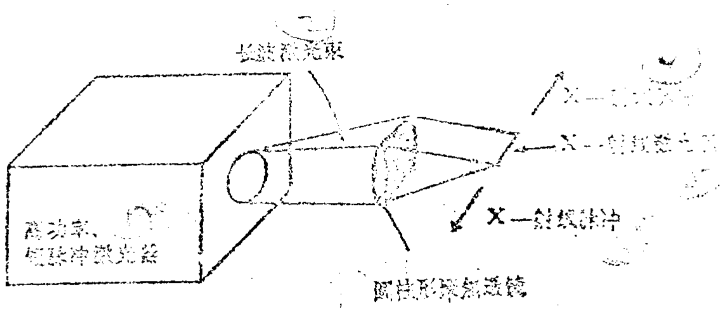

Fig.6-1 In order to make X ray lasers capable of real operation, it is necessary to take large amounts of energy and rapidly accumulate them in laser materials. One type of common method is to utilize short pulses with relatively long wave lengths emitted in laser devices associated with making laser nuclear fusion tests and of very high power. Light beams focused on X ray laser media are capable of producing the required high power emissions. In the Fig., laser light produced by lasers of very high power pass through cylinder shaped lenses. Focused in a straight line, this straight line is equivalent to combining all the points associated with the foci of ordinary spherical lenses. Fine fibers are the media of X ray lasers. It is volatilized by the laser light of another laser. However, before volatilization, it is possible to produce fast X ray scintillation. Because there is no reflector mirror here, this type of X ray laser, therefore, produces two beams of laser light shot out from the two ends of the fibers.

Key: (1) High Power Short Pulse Laser (2) Long Wave Laser Beam (3) Cylinder Shaped Focusing Lens (4) X Ray Pulse (5) X Ray Laser (6) X Ray Pulse

Producing X ray lasers requires creating a condition of particle reversal. This is capable of using two types of methods for realization. One is to utilize X rays to stimulate atoms to high energy levels. The second is to utilize atom or ion /127 electron collisions to transmit energy. These two types of methods both will lose large amounts of energy in operating media, making operating media change into plasma. When high temperature plasma expands, it rapidly cools. When electrons and ions in plasma compound, they then produce particle number reversal. Britain's Heer (phonetic) college made successful

experiments in this area. They added strong laser light pulses with sustainment periods shorter than 10^{-12} seconds to carbon fibers with diameters of a few microns, producing high temperature plasma. Following along with plasma expansion and rapid cooling, carbon nuclei which have lost all electrons begin to capture electrons. Electrons after capture are at low energy levels. Stimulated radiation with a wave length of 182Å is produced during this process (see Fig.6-1).

6-3 Mutual Effects of X Rays and Substances

Despite the fact that X ray characteristics are difficult to precisely measure, when there are mutual effects between them and materials, they are capable of producing a number of clear effects. X rays are capable of making atoms associated with the interior of solids ionize (including solid materials in electronic circuits). This type of effect between X rays and matter produces electron showers capable of causing loss of memory capability in semiconductor equipment. In conjunction with this, it causes temporary or permanent loss of effectiveness. X ray pulses of adequately high strength are capable of making physical properties of materials go down or make surface layers vaporize or produce shock waves having destructive properties. Low doses of X rays are capable of making the human body develop cancer or variations. High doses of X rays are capable of killing people. These effects all possess military applications. This is particularly true of the point about making guidance and control systems lose their effectiveness.

X rays' ability to go through matter depends on their wave length. Generally speaking, the shorter wave lengths are, the stronger are their transmission characteristics--for example, 2.7 Å X rays are capable of penetrating 6.9 microns of iron. However, 0.56 Angstrom X rays are capable of penetrating 64.1 microns of metal. The penetration thickness more or less increases 10 fold. When X rays see through the human body, they are capable of getting high contrast images. This is due to the constituent elements of human body soft tissues--which are primarily hydrogen, carbon, and oxygen--and these soft tissues having very good transparency to X rays. However, the primary constituent of bones, calcium, is capable of intensely absorbing X rays.

In the atmosphere, the effects of X rays have a type of commonly seen tendency, that is, the shorter wave lengths are, the stronger transmission characteristics are. However, X rays in the atmosphere certainly do not propagate as far as people think. At sea level, when 1Å X rays in the atmosphere penetrate 2 meters, X ray strength has already weakened a half. With regard to 10 Å X rays, the situation is then even more serious. When they penetrate 1.5 millimeter thicknesses of air, strengths then weaken one half.

Intense atmospheric absorption limits X ray weapon utilization in space. Even if outer space has no atmospheric absorption effects, if, however, orbiting X ray weapons shoot beams at the ground, they will also be completely absorbed away by the atmosphere. 1Å light beams, when they reach a point 60 kilometers from the earth's surface have already been half absorbed. However, beams of 10Å light have half absorption altitudes at 110 kilometers above sea level. This type of atmospheric absorption effect is the primary reason allowing us to avoid meeting with the harmful effects of X rays associated with solar emissions and ultraviolet radiation.

Considering transmission effects, even in outer space, there is also a tendency to use relatively short wave lengths of X rays to act as weapons. One of the reasons is that relatively short wave lengths will more effectively penetrate the metal shells of targets. Another reason is that, in outer space, the atmosphere can reach 100km above sea level. This type of residual atmosphere is adequate to block the propagation of relatively long wave length X rays. Potential applications of X ray laser light are not only limited to acting as weapons. Applications of this type of laser in the area of living cell high resolution holography also receives broad attention. Other applications include high precision wiring diagrams when manufacturing

semiconductor integrated circuits, medical diagnosis and treatment, metallurgy, radiation chemistry, atomic physics and energy spectroscopy research, materials structure research, observation of laser fusion reactions, and so on. However, there is no single item which can reach the importance of the military area with the result of being able to support a large scale research plan.

Theorists are beginning to pay attention to even shorter wave length rays, that is, γ rays. However, the difficulties associated with manufacturing γ ray lasers (or called "gu(illegible)saisi (phonetic)" are even more difficult to imagine. A research team composed of three theoretical physicists from the U.S. and the U.S.S.R. said this kind of thing: "With regard to mankind, the difficulties met with in association with γ ray lasers are a type of challenge not yet experienced." What should be explained is that these few theorists are optimistic. In conjunction with this, they believe that manufacturing γ ray lasers is eventually possible. /130

6-4 X Ray Laser Headway

Research work in search of X ray laser light already has a history or more than 20 years. However, the openly published research results are certainly not outstanding. There are roughly two types of possibilities in association with this. One is that X ray lasers still have not attained that kind of huge breakthrough similar to those associated with visible light. The other, by contrast, is that there is a very great relationship between X ray lasers and military uses; stemming from the requirements of secrecy, there are a number of articles which have not been published. In 1973, U.S Youta (phonetic) University's veteran scientist John Kaipuluosi (phonetic) announced that he had demonstrated the X ray laser; however, his

experimental results (illegible) very numerous. Other scientists were unable to duplicate his experiments. One U.S. magazine "Laser Focus" called his results "neither laser nor X ray". As far as John Kaipuluosi's (phonetic) results are concerned, they have not been seen as an important breakthrough in association with X ray lasers. However, they still have very great motivating and stimulating effects on the research work of people searching for the X ray laser.

Besides Youta (phonetic) University, a number of other scientists also made experiments in this area. For example, in 1974, Paris University's Jie(illegible)er (phonetic) asserted that small laser gains had been observed in expanded aluminum plasma produced in pulse lasers. However, people doubted this result in the same way. The reason was that it was possible to explain his results using other mechanisms and not using laser gain.

In 1977, two Soviet scientists-- I. Subieerman (phonetic) and V. Lietuoliefu (phonetic)--used calcium which had lost 10-12 electrons and titanium plasma as well as chlorine plasma which had lost 7 electrons and got stimulated radiation within the wave length ranges of 350-850 Å and 580 - 780 Å respectively. However, due to bad reproducibility, as a result, people were still not convinced. /131

Due to the fact that X ray lasers have many very important uses, a number of scientists are striving mightily in the search. Peoples' paths of exploration are very numerous. Besides the method of directly producing X ray lasers, there are a number of other ideas. For example, there are people making use of nonlinear effects associated with lasers. That is also nothing else than, when lasers penetrate materials, light will appear with a frequency twice the frequency of the incident light. There is also another type of method to produce X ray lasers,

that is, use the energy associated with nuclear explosions in order to stimulate X rays. Some people believe that this is the most promising method.

6-5 Nuclear Explosion Driven X Ray Lasers

In 1981, the U.S. "Aviation Week" revealed startling news. The U.S. Laurence Livermore laboratory used small nuclear explosions to achieve X ray lasers. The method is to arrange approximately 50 fine wires of operating medium around the periphery of a nuclear bomb. Making use of the various types of radiation produced by nuclear explosions to pump the laser media, it makes the atoms in the fine wires stimulate to high energy levels. X rays produced by nuclear explosions stimulate the media in each fine wire, causing X rays within fine wires to multiply and amplify forming high power X ray pulses (see Fig.6- 2).

The driving force associated with this type of laser comes from military uses. Edward Teller--famous as the creator of the U.S. hydrogen bomb--is an important personage who strongly supports this work. He demands that the government supply funding for this. In conjunction with that, it is asserted that within a few years it will then be possible to see results.

There are still quite a few problems which await solution with regard to taking this type of nuclear explosion driven X ray laser and having it act as a weapon. Due to the fact that, at the present time, there is still no X ray laser system with good properties, as a result, the X ray laser beam direction associated with each fine wire is determined entirely by the fine wire itself. Fine wires making up operating material must be very straight. Moreover, they are rigid. At the same time fine wires must be very long and very thin. Each wire is nothing else

than a laser. In the process of nuclear explosions, it is necessary that these fine wires all be arranged in appropriate positions. In conjunction with this, there is a requirement not to experience the influences of the explosion shock. This is very difficult. Due to the fact that each thin wire has an additional tracking directional system, this then makes X ray lasers complicated. This type of laser weapon is primarily used to cope with all out ballistic missile offensives. Moreover, it can only be used once. This is not ideal (see Fig.6-3).
Due to the fact that X ray laser weapons primarily attack missiles which appear in large groups, as a result, if one wants to take this kind of weapon and fire it into space orbit, not only do a number of technical problems exist. Moreover, taking nuclear bombs and sending them into outer space orbit violates the test ban treaties signed by the U.S. and the U.S.S.R. For example, it violates the nuclear weapons test ban treaty of 5 August 1963 signed by the U.S.S.R, the U.S., and the U.K. in Moscow (or nuclear treaties banning the carrying out of tests in the atmosphere, in space, or under water). Although X ray laser weapons have a number of advantages and have received serious attention from military personnel, the production of X ray laser beams, however, as well as exerting their effects as weapons still have a number of problems.

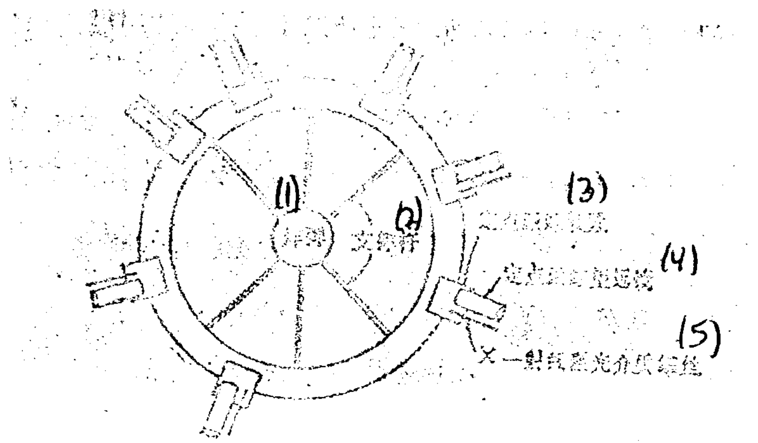

Fig.6-2 Basic Structure of An X Ray Laser Combat Station Tentatively Designed by U.S. Military Planners. A circle (illegible) equipped with approximately 50 X ray lasers is set on the periphery of a nuclear explosion. For the sake of simplicity, in the Fig., only a small number of laser devices are (illegible). Each X ray laser fine wire medium requires having its own fixed point tracking system. There is a possibility of fitting them out with tracking telescopes. In this way, it is then possible to determine target position, and, in conjunction with this, allow X ray lasers to accurately aim at them thereby (illegible) outputed laser pulses on target. In order to track distant targets, telescopes must use large model optical components. They can be much larger in volume than X ray laser media wires. If it is necessary to maintain unusually precise tracking, it is then necessary to take tracking equipment and install it on another satellite.

Key: (1) Bomb (2) Cross (Illegible) Rods (3) Fixed Point Tracking System (4) Fixed Point Tracking Telescope (5) X Ray Laser Fine Media Wire

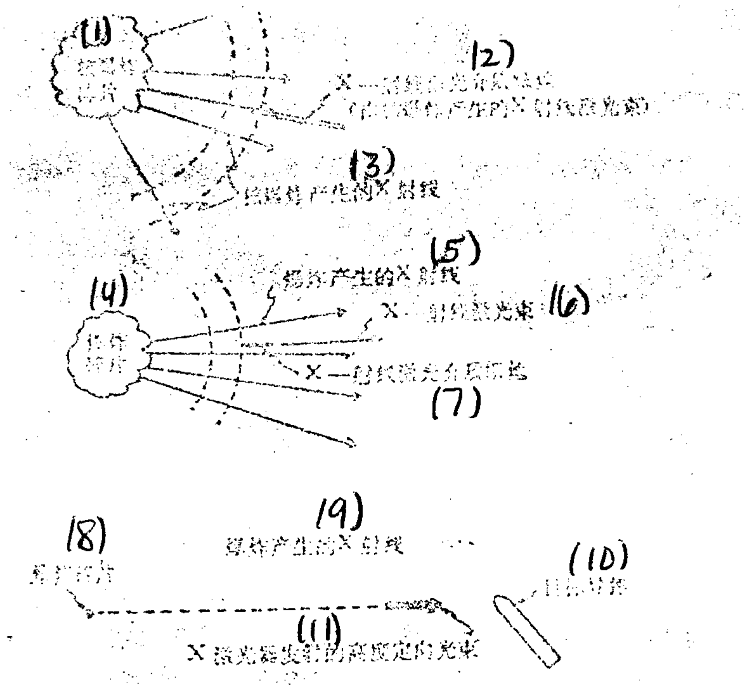

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Fig.6-3 X ray laser fine media wires are one constituent part of a space combat station. As far as X ray laser devices excited by X rays produced by nuclear explosions (top Fig.) are concerned, they cause the emission of beams of very thin X ray laser light before shock waves given rise to by nuclear explosions reach them (middle Fig.). X rays produced by nuclear explosions diffuse right out into space and are not capable of very good utilization. However, X ray laser beams will be tightly focused by space combat stations on very distant places, and, in conjunction with this, destroy targets there (bottom Fig.). X ray pulse periods are very short. From the bottom Fig. it is possible to see that X rays are capable of being focused together, and, unlike laser beams in general, stretch out along a very long longitudinal straight line in that way. In laser light put out by lasers, a portion is capable of being put out in a direction opposite to that of the main beam. However, X rays produced by nuclear explosions propagate along the direction of the length of fine laser media wires. Therefore, the great majority of X rays will shoot out the end of thin laser media wires.

Key: (1) Nuclear Explosion Fragments (2) X Ray Laser Thin Media Wire (X Ray Laser Beam Produced by Nuclear Explosion) (3) X Rays Produced by Nuclear Explosion (4) Explosion Fragments (5) X Rays Produced by Explosion (6) X Ray Laser Beam (7) X Ray Laser Thin Media Wire (8) Explosion Fragment (9) X Rays Produced by Explosion (10) Target Missile (11) High Energy Directed Beam Emitted by X Ray Laser

6-6 γ Ray Lasers

γ rays are electromagnetic radiation with even shorter wave lengths than X rays. If it is possible to manufacture γ ray lasers, then, γ ray laser weapons will have even more power than X ray laser weapons. They really can be called "death rays". Because of this, the potential of γ ray lasers in fields of military application are even more attractive.

γ rays, X rays, and visible light all belong to electromagnetic radiations. However, the energy of γ ray photons will be much higher than the energy of X rays. γ ray energies are capable of reaching mega electron volts or higher. They are high energy photons radiated from atoms in stimulated states after loss of nuclear stimulation. At the present time, people's knowledge of atomic nuclear structure is still not as deep as people's knowledge of atomic structure. Although people--with regard to atomic energy level structure--have already accumulated large amounts of data, comparatively speaking, however, data accumulated by people with regard to atomic nuclear energy level structure is, by contrast, relatively scarce. As a result, the realization of γ ray lasers still has a lot of difficulties. Normally, the production of γ ray laser light requires laser media to possess the condition of particle number reversal. γ rays are put out atomic nuclei lose stimulation. However, making atomic nuclei stimulate to high energy levels to form a particle number reversal is unusually difficult. This is because, in stimulation processes it is necessary to have very high input powers. The highness of input powers is capable of making operating media and other materials change into a fused state. There are some scientists who attempt, from a different angle, to surmount this difficulty. They make use of atomic nuclei of the same mass but different energy states in order to

realize particle number reversal. What is meant by these isomers is nothing else than two types of atomic nuclei associated with the same constituents (that is, neutron number and proton number the same), however, placed in two types of different energy states. Nuclei of the same mass but different energy have one very large advantage. That is nothing else than that atomic nuclei placed in high energy states certainly do not very rapidly decay to lower energy states. By contrast, they stay in high energy states for quite long periods. With regard to different nuclides, these periods are different. These can even reach a few hundred years or longer. Using isomer states can slowly input energy making nuclei be placed in high energy states and store them up thereby creating a particle number reversal condition.

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In 1975, a Rumanian scientist, Bitelasiku (phonetic), brought up that fact that, with regard to γ ray sources or absorption bodies, energy associated with nuclear recoil losses (corresponding to the recoil when a rifle is fired) is capable of using a second photon associated with an overall loss equal to absorption energies in order to compensate. This process is called a coherent multiple photon process. Utilizing this type of process to reach particle number reversal in order to realize a nuclear laser pump, it is possible to avoid the several difficulties met with by traditional single photon pump processes. Tests at the present time verify that this type of idea is feasible. Resolving feasibility problems associated with γ ray lasers depends on: (1) selecting optimum isomers; (2) selecting the lowest energy level associated with the production of laser output; and (3) opting for the use of appropriate drivers to make this type of isomer produce particle number reversal.

If γ ray laser processes achieve realization, then, the power released by each kilogram of material can reach 3×10^{21} watts (the total power of the entire U.S. electric grid is 10^{12} watts). This can be called a "cosmic level" artificial light source.

As far as achieving γ ray lasers is concerned, it involves a number of fields of knowledge. These do not belong within the discussion range of this book. However, research work related to γ ray lasers is indeed being nervously carried out in a number of laboratories--for example, Dekesasidikelinsi (phonetic) team is in the midst of evaluating two types of new γ ray laser ways of collecting light spectrum data. One is a nonlinear analogy associated with reverse Situokesilaman (phonetic) scattering. Visible light wave band laser photons are used to irradiate isomers in order to produce "reverse Situokesilaman" γ ray output. Another type uses noncoherent X rays to take a certain type of isomer and raise it to approach one of the normal energy levels associated with the isomer in question. From there, there is a transition to a short lived laser light energy level. After that, γ rays are emitted. Gelinsi (phonetic) says that the success or failure of these two types of methods depends on when as well as whether or not appropriate isomers can be found.

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Los Alamos took a step on the road toward γ ray lasers which is that it will demonstrate the capability to select ionized mercury isomers. This is an unusually important step toward isomers separated from other nuclei in order to facilitate the preparation of γ ray laser crystal materials collection.

Even if the progress discussed above is obtained, the realization of γ ray lasers is still many years in the future. Research personnel believe that a reasonable time table is twenty years.

Chapter 7 PARTICLE BEAM WEAPONS AND ELECTROMAGNETIC GUNS

Imagine for a minute the process of lightning in the natural world as familiar to everyone. We can then have a rough understanding of real particle beam weapons. Before lightning is produced in the atmosphere, electrons are separated from atoms. A very high static electric potential (electrical potential difference) forms between cloud layers and the ground. Electrical potentials can reach 10^9 volts. This is adequate to allow air puncture breakdown. Air is normally an insulator. However, when lightning is produced, within the short time periods between cloud layers and the ground, it is still possible to pass very strong electric currents. Although particle beams and natural lightning processes have very large differences, the two, however, are the same in the huge destructive effects they possess.

A clear track will remain at places where lightning strikes. Quite a few people seem to harbor various types of fear psychologies toward lightning. The first time lightning is seen, small children will be frightened and lie down and hide or hug their parents very tightly. Most people know that, when storms are met with, one must, as much as possible, avoid staying on open plains and mountain tops in order to avoid becoming the target of a lightning strike. However, even if people do that, they are still certainly not sure they will not be hit. This fact tells us: the energy of lightning is certainly not precisely "directed". Between the cloud layer and the ground, it advances along a tortuous path. Clearly, there is an intimate relationship between the path and the state of the atmosphere. Large, high buildings and trees often become the targets of lightning strikes.

Weapons researchers are earnestly searching for a type of physical process analogous to lightning, and, in conjunction with that, to use it to act as the foundation for directed energy weapons. The same as in lightning, it is possible to use high voltage to make electrons, protons, or atoms carrying positive and negative electric charges obtain extremely large energies (electric fields and magnetic fields have no effect on neutral particles or particles with net electric charges of zero). However, how it is then possible to make beams accurately hit targets is still an important question.

People conjecture that particle beam weapons have some similarities with the effects of laser weapons currently under development. Due to the fact that there is a consciousness of this kind of similarity, the Pentagon takes particle beam /138 weapons, lasers, and microwaves and crowns them all with the name "directed energy technology". Comparing the various individual roles they play on the battlefield, their similarities technologically are even greater. Lasers and particle beam weapons utilize the same ignition control systems. Laser beam weapon development also uses high power technology associated with laser weapons. Of course, they also have very great differences.

In view of the existing differences, it is possible to imagine that the problems run into in developing particle beam weapons and the problems run into in the development of laser weapons are definitely different. Different from optical quanta, particles possess mass. As a result, it is possible to penetrate more deeply into target objects. In this way, the destructive effects they give rise to are often more severe than lasers. However, the status of laser transmission in the atmosphere will be much better than that of charged particle beams. That is also nothing else than laser energy strictly advancing in accordance with tracks predicted by relativity theory. With regard to

particle beam weapons, the key problem is how to make particle beams hit the target. Particle beams, once launched, are confirmed to create target damage unless they lose all their energy during the process of transmission.

Particle beam systems used for military purposes--due to different military roles--can be divided into several parts. Looking at Fig.7-2, in the part associated with the production of charged particle beams, there has today already been relatively complete development. As far as the results of beams and atmospheric effects are concerned, they make repulsion forces between particles in beams weaker. However, once beams enter into outer space, they will then rapidly diverge due to charged particle repulsion forces. Besides this, due to the effects of geomagnetic fields, when beams penetrate long distances, they will be bent by in ways which are very difficult to predict and complicated. At the same time, electrical charges produced in air will take energy from beams, finally causing beams to stop. High energy neutral particles in space will not diverge due to the effects of geomagnetic fields. This is very appropriate to the long distance applications required in ballistic missile defense. However, when they are transmitted in air, they will diverge very fast. This is nothing else than the electrons they themselves have stripped off causing neutral particle beams to gradually turn into charged particle beams. This process causes the strength of neutral particle beams to very rapidly weaken.

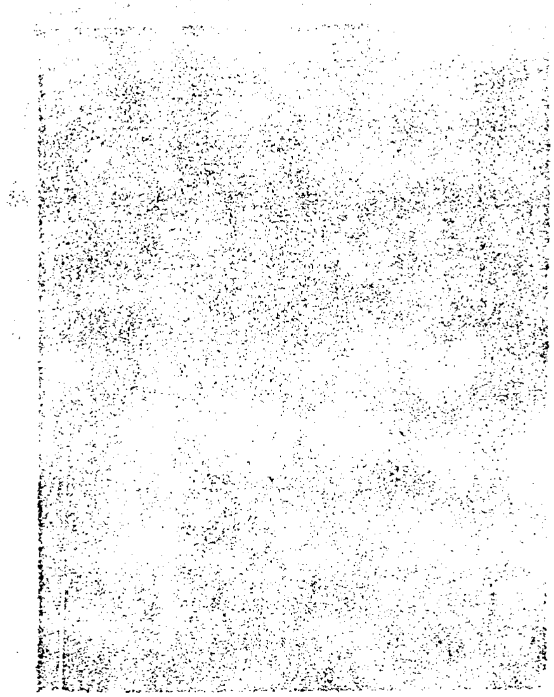

Fig.7-1 During one test at Albuquerque's (illegible) national laboratory, a view of sparks (illegible) flying during high voltage switch (illegible) operation. These switches, within very short pulse durations, are capable of turning on (illegible) 30 billion kilowatts of power. They are also a part of the installation associated with Sangdiya (phonetic) particle beam nuclear fusion accelerator tests. As is described later (illegible), particle beam nuclear fusion accelerators are primarily applied to nuclear fusion areas of research. However, similar technologies are also capable of application to particle beam weapons areas. This photo clearly shows that there are only energy losses when particle beam pulses are being turned on and off. (illegible) this time, powers associated with particle beams themselves are then even higher.

Obviously, particle beam weapon development plans have a number of difficulties which must be overcome. The attitude of the Pentagon is: "Particle beam technology, at the present time, is still in an early study and exploration phase associated with a number of basic problems which need to be resolved, such as, feasibility. As far as technologies at the moment are concerned,

it is still not possible to say, theoretically speaking, whether there is a very great distance between the very mature state of technology which has already been developed and military requirements." In short, military heads do not believe that this complete set of ideas is actually feasible. Even if it is feasible, before taking this idea and turning it into weapons associated with practical applications, there is still a very long road which must be traveled. Those people supporting the development of beam weapons are clearly too optimistic. There are also a number of people who believe that the whole idea is absurd. In the 1982 fiscal year, U.S. particle beam technology investments only accounted for one tenth of the whole directed energy budget. This seems to be a suggestive warning to people hot on particle beam weapons in the Pentagon.

If one wants to get clear the problems discussed above and the basic principles associated with particle beam weapons, there is a need to glance over these technologies. Here, only a few simple, to the point descriptions will be made. Detailed descriptions of physical processes are too complicated. They exceed the range discussed in this book.

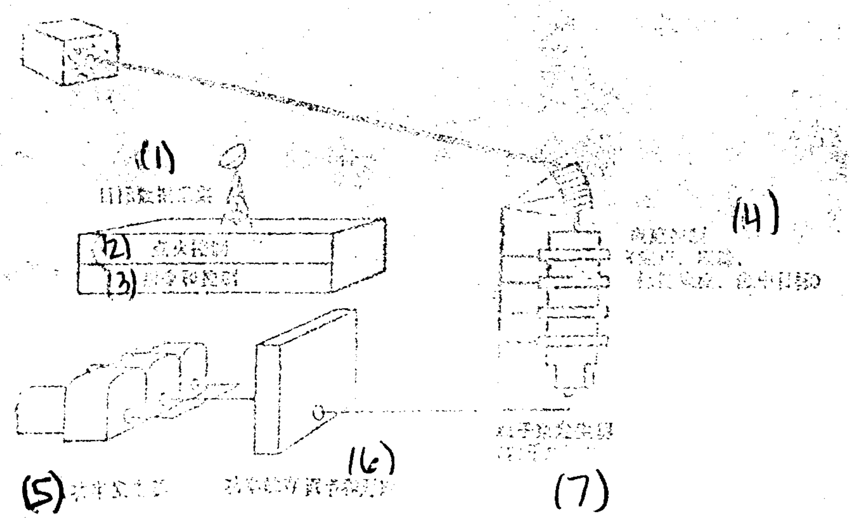

Fig.7-2 What is shown in the Fig. are key components associated with particle beam weapons confirmed by U.S. military designers. Bottom left is the power system associated with particle beam generators. Particles produced by it (illegible) directed toward targets. Particle beam control systems directly control beams operating the target (illegible) and initiation systems in the middle left of the Fig.

Key: (1) Target Data Collection (2) Ignition Control (3) Command and Control (4) (illegible) Control (fixing, tracking, (illegible) beams, (illegible) targets) (5) Power Generators (6) Power Storage, Adjustment, and (illegible) (7) Particle Beam Generator (particle (illegible) device)

7-1 Particle Beam Production

As far as producing beams is concerned, one must first of all produce particles. This type of particle can be electrons, protons, positive ions (atoms that have lost one or several electrons), or negative ions (atoms which have gotten one or several electrons). After that, these charged particles undergo acceleration by electromagnetic fields, hitting targets. Producing high energy beams requires energy supplies associated with high power electricity sources with voltages of approximately 106 volts as well as high voltage high current capabilities able to initiate and switch off in time period ranges of approximately the order of magnitude of 10^{-9} seconds.
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The development of particle acceleration technology has already gone through an approximately 50 year time period. Moreover, development has been very rapid. The main reasons lie in the fact that basic particle and nuclear physics research has gotten a number of huge financial support grants from the national government. It is only in the most recent development that the pace has slackened. In the past twenty years, new applications of accelerators have developed without a break. The primary reason is that accelerator designers are very (illegible). At the same time, there is the greatest interest. Not only this, but, in the past twenty years, pulse powers have also had a development which people have difficulty believing. Voltages can reach levels of 106 volts. These technological developments give rise to military interest in particle beam weapons.

What particle beam producing systems need first of all is a particle source. In electron accelerators, particle sources are gotten through adding a high voltage pulse to two metal electrodes in a vacuum to produce spark discharges. Using scientific terminology to speak about this, this system is called

a "vacuum diode". After that, electrons emitted from negative electrodes (cathodes) fly toward positive electrodes (anodes). Through appropriate design and arrangements, electrons will not be absorbed by anodes but penetrate anodes and enter into acceleration cavities.

Electron pulses also use the same type of methods for production. Taking a very short high voltage pulse and adding it to two electrodes, positive electrodes (anodes) will then produce positive ions. They are capable of coming from ionization associated with solid materials. It is also possible to produce them from gas electrical discharge processes. If one hopes to produce negative ions, it is possible to take electrons and inject them into positive electrode space, causing electrons to adhere to gaseous atoms in the vicinity of anodes. In this way, negatively charged ions are then formed. After that, they are drawn out into accelerators. Through acceleration adjustment voltages, it is then possible to take the hoped for charged particles and send them into accelerator cavities (for example, atoms which have only lost one electron). Using the same type of methods, through stripping off hydrogen atom electrons, it is possible to produce proton beams. Similarly, it is also possible to produce the heaviest element in the natural world--uranium ion beams.

As far as the powers of electron beams and proton beams acting in military uses are concerned, at the present time, they are still not able to take the form of continuous outputs but are only capable of very short pulse forms. Under the effects of high voltage, electrons and protons are accelerated and receive energy. The simplest form associated with the supply of energy is the storing of a certain amount of electric charge in a /142
capacitor. If there is an exterior demand, it is then possible to take electric charge and speedily release it. That is also nothing else than the release of energy. The simplest capacitor

is the insertion of an insulation medium between a pair of metal plates. When voltage is applied to it, capacitors then store electric charge. The more electric charge is stored at a fixed voltage, the more energy the capacitor possesses. When the two plates come in contact, then, there is an electric current which flows across--right on until the stored energy is completely released and then stops. When structurally complicated capacitors add high voltages, it is possible to release pulse currents of very great strength. The problem is that the volume of this kind of capacitor is too great. Manufacturing costs are too high, and efficiencies are still not high. Its utilization for demonstrations or within laboratory ranges is very good. However, it cannot be used in actual weapons applications.

We are currently in the midst of studying other models of high power pulse sources with more compact structures and even lighter weight. One type of method is based on explosion forces compelling electrically conductive plasma (ionized gas) to enter into and install itself inside generator coils within superconducting magnets. Magnetic fields capturing plasma and compressing it inside coils as a result produce an electrical pulse within generators. Openly published reports clearly show that Soviets are also in the midst of utilizing analogous methods in order to obtain strong pulses. They are currently in the midst of studying whether or not it is possible to use mechanical rotation methods to store and output this type of energy.

When utilizing pulse powers, there are also other complicated problems. One is none other than the problem of transmitting high power pulses themselves. There is a need to create certain types of conditions to make electrical pulses produced by pulse sources turn into the energy required in association with particle beam generators. This requires taking high voltages and using pulse methods to obtain multiplication. As far as normal switch operation is concerned, when voltages

reach several hundred thousand to several million volts, it is not so simple. Acting as weapons systems, the need to take this type of high voltage and turn it on and off several times each second is extremely difficult. This type of research work associated with high degrees of difficulty, in recent years, has already attained very great progress. However, there is still a need to travel a very long road, and only then will it be possible to reach the requirements put forward by military applications. /143

7-2 Particle Accelerators

Once electron or ion beams are produced, there is then a need to accelerate them to very high speeds, making them possess very large energies. This simply requires short ion pulses through strong electric fields thereby making them obtain energy.

Ion energies depend on electric charge states and electric field strengths they go through. Physicists often use the unit electron volt in order to describe energy. The numerical value of 1 electron volt of energy is the energy acquired by one electron crossing a 1 volt electric field. Particle energies used in the weapons area reach several million electron volts.

Particle beam power in a pulse refers to the energy associated with each particle multiplied by the number of particles. It is just like the number of electrons crossing a section of conductor wire in a unit time determining current magnitude. Particle numbers in beams determine beam strength. Despite the fact that accelerator specialists are capable of making each particle reach very high energies, they, however, are

still not able to reach the high current strengths required by beam weapons. Weapons specialists are in the midst of developing special high current strength accelerators. In order to understand phenomena produced when currents are high, the U.S. Livermore laboratory built an advanced test accelerator (ATA).

Accelerators used in beam weapon systems do not have fixed forms. Ideas which have very great differences between each other are all under study. In a number of operations which do not pertain to "directed energy" project support, there are many basic technologies of a general character. From these different experiments, the Pentagon hopes to get valuable things.

In the past few years, the Pentagon (illegible) a portion of energy and funding was spent on accelerator development. The primary manifestation of this type of effort is two electron linear accelerators built at Laurence Livermore laboratory. The first one is an exploratory test accelerator (ETA). It began operation in 1971. This system is a by product of the Navy's previous "enjoy the inheritance at leisure" project. In 1978, this project was put into the Defense Advance Research Planning Agency project items. This system is capable of producing 5 million electron volts, ten thousand ampere electron beams, and pulse widths of 50x10 (illegible) seconds. Within short periods of time, it is possible to produce 1000 pulses each second. /144 However, on average, it is only possible to release 5 pulses each second.

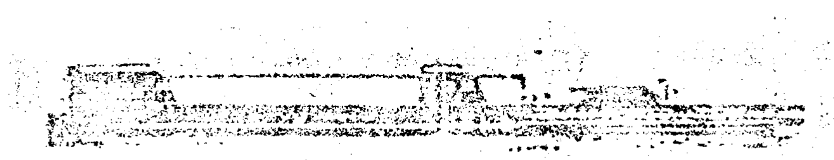

Fig.7-3 Lateral Schematic Diagram of Advanced Test Accelerator Systems (ATA) at Laurence Livermore National Laboratory. (Illeg.)

Advanced test accelerators (ATA) are larger, more advanced accelerators (ATA) seen in Fig.7-3. This advanced accelerator is used with speeds of the same sort as ETA to produce electron pulses with energies of 50x10 (illegible) electron volts. Livermore laboratory researchers have indeed been heartened by ETA accelerator results. In the first year of ETA operations, despite the influences of earthquake and repairs, which used up over 10 months of time, it still "completed" 80% of predetermined experimental projects. Defense Advanced Research Planning Agency officials say: "After the building of this system (ATA), it will be the strongest accelerator in the free world." In the latter part of 1982, Livermore administrative officials, when talking about accelerator plans, said that, in the early part of 1983, it would then be possible to meet with the public. It is no ordinary directed energy weapon project (see Fig.7-4).

Exploratory test accelerators (ETA) and advanced test accelerators (ATA) both belong to test accelerators. Their series of acceleration electrodes are all arranged in linear forms. When operating, pulse voltages change electric fields added to beams making particles accelerate. Due to a very large number of electrode accelerations, it is finally possible to make particles reach very high energies.

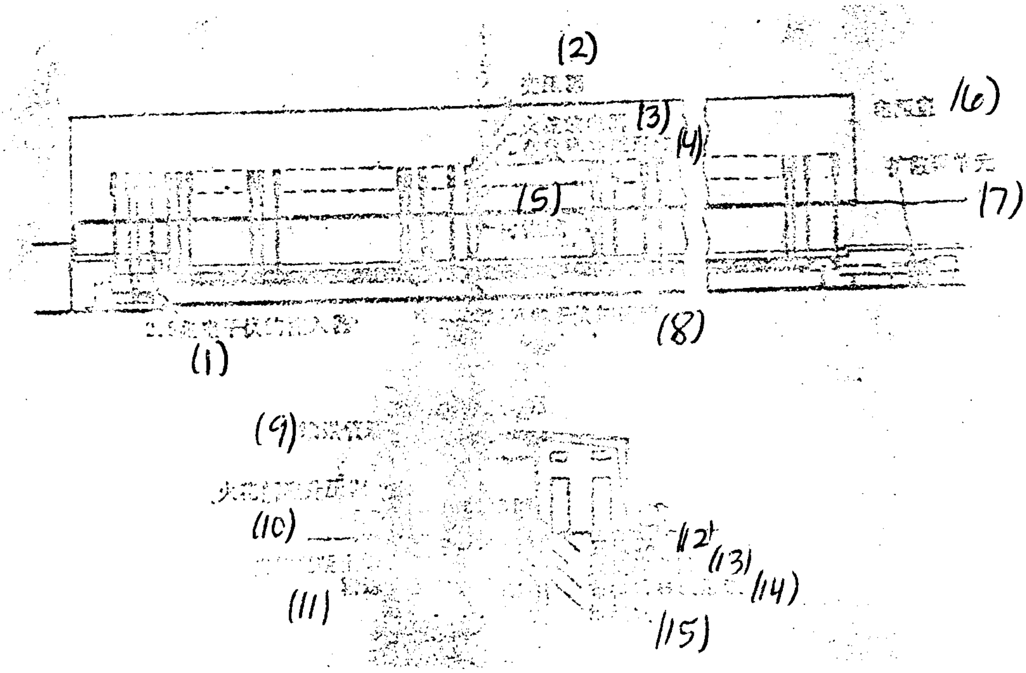

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Fig.7-4 Principal Parts of the Advanced Test Accelerator (ATA) in (illegible) Laurence Livermore Laboratory. The left side is a particle injector. The 190 acceleration elements in this system account for most of the length of the entire system. The overall system length is 78 meters. When electrons go through this (illegible) accelerator, all together, they are able to acquire energies of 2.5x10(illegible) electron volts. The right side of the electrical equipment room is beam transmission systems. The far right is a test target area. The lower Fig. is an accelerator channel cross section diagram.

Key: (1) 2.5 Mega Electron Volt Injector (2) Transformer (3) (Illegible) Electrical Device (4) (Illegible) Formation Line (5) (Illegible) (6) Electrical Equipment Room (Illegible) (7) Diffusion Pump Unit (8) (Illegible) Electron Volt Acceleration Cavity (9) (Illegible) (10) Spark (Illegible) (11) (Illegible) (12) Transformer (13) Spark Discharge Device (14) (Illegible) (15) (Illegible)

The operating principles of the pulse transmission linear accelerator (RADLAC) of Sangdiya (phonetic) national laboratory in Albuquerque, New Mexico, are similar to this. The primary difference is in drive circuit components. This system is capable of making electron energies $9x10^{(illeg.)}$ electron volts. In conjunction with this, it produces 25000 ampere currents. This project was supported by the Department of Energy and the Air Force Weapons Laboratory. The beam effects of the systems in

question are capable of producing large amounts of X rays on targets, extremely similar to the effects of nuclear /146 explosions. A bigger, more powerful accelerator, "RADLAC II", is also in operation. On the basis of March 1987 reports, the electron beams it produces have already reached 16 mega electron volts and 30 thousand amperes. The Defense Advanced Research Planning Agency also has an accelerator test project code named "White Horse". It is installed at the Los Alamos national laboratory in New Mexico (see Fig.7-5). The accelerator in question uses an 80 megahertz high frequency field. This high frequency field is formed by a four electrode field and not the ordinary two electrode field.

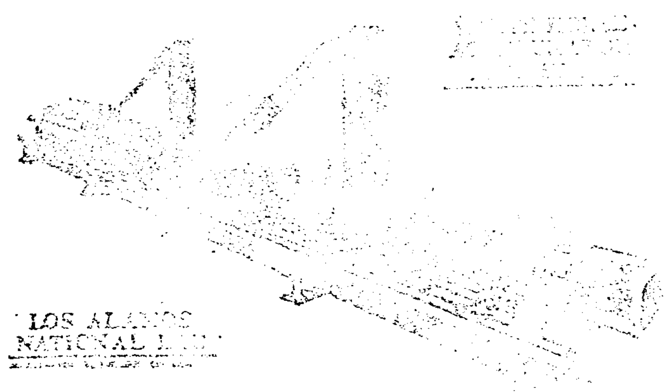

Fig.7-5 Sketch of the Accelerator Code Named "White Horse" at the Los Alamos National Laboratory. The development of this system has gotten the support of the Defense Advance Research Planning Agency. Plans are to use it in order to carry out neutral particle beam feasibility tests.

This technology was first put forward by the Soviets. Later, the Los Alamos laboratory made some improvements. Speaking in concrete terms, they are nothing else than focusing beams at the same time they are accelerated. This system is called radio frequency quad electrodes (RFQ). It is already widely used in particle accelerator technology. The system in

question will be used in order to accelerate negative hydrogen ions. At accelerator terminals, the excess electrons on negative hydrogen ions are stripped off in order to produce the neutral particle beams required in outer space.

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For the sake of other uses related to the military--for example, such simulations as inertia restricted fusion and nuclear reactions--there are quite a few other models of accelerators just now in operation, under construction, or being designed. The idea of inertia fusion is taking strong particle beam pulses and adding them to hydrogen isotope targets, producing high density plasma and causing hydrogen nuclei in plasma to fuse together in conjunction with the release of energy. The long term objective of scientists is to obtain the energy mankind needs from this technology. At the present time, the primary interest is in simulations of hydrogen bomb explosions on a small scale. The physical processes associated with this type of micro explosion are unusually similar to the physical processes associated with hydrogen bomb explosions. Because of this, nuclear weapons designers have a special interest in the results of inertia fusion tests (these test results are all classified). Radio radiation produced by inertia fusion explosions are also very similar to radio radiation produced by hydrogen bombs. Because of this, utilizing it, it is also possible to use it in order to study the effects of electromagnetic radiation on military equipment. Up to the present time, these military effects studies have all been financially guaranteed by inertia fusion research expenses of the U.S. Government. Light particle beam operations are concentrated at Sangdiya (phonetic) national laboratory. They first concentrated their vision on electron beams. Following that, in 1979, attention turned to proton beams. The Sangdiya (phonetic) particle beam fusion accelerator (PBFA-I) is capable of producing electron beam pulses of $30x10^{-9}$ watts. At the same time, Sangdiya (phonetic) researchers are just in the midst of working

with ion diodes linked together with expectations of producing directed particle beams of very great power. A larger installation (called PBFA-II) is planned to be completed in approximately 1986. Correspondingly, the Department of Energy has begun relevant heavy ion beam fusion plans on a relatively small scale. These have been primarily carried out at Los Alamos as well as a number of other laboratories.

Particle beams have also been used in tests associated with checking various types of nuclear reactions. In this area, as far as such pulse transmission linear accelerators as those mentioned before are concerned, the electron beams produced by this kind of system hit on targets and then are capable of producing such "hard radiation" as X rays and γ rays. At the moment, simulations of nuclear reactions have become very important. Taking military equipment and exposing it to this type of radiation, observations are made of how their ultimate results will be in a nuclear war. Doing this to carry out checks will be much cheaper than using underground nuclear weapons tests. /148

Although those experimental accelerators were initially used for other purposes, the Pentagon also, however--through these test data associated with accelerators--recognized a number of key problems associated with accelerator technology: that is, whether or not it is possible to produce high energy particle beams required for military purposes, with adequately high efficiencies, and compact structures; whether or not particle beam producing systems are able to produce unusually quickly pulses to block ballistic missile attacks; and, what the efficiencies of different types of particle beams produced are like.

7-3 Beam Transmission

At Livermore and Los Alamos, the Defense Advanced Research Planning Agency's two primary projects both concentrated their attention on accelerator technology. Particular stress was laid on being able to give accurate estimates of potential capabilities associated with the production of high current pulses at high repetition rates as well as not only on accelerators for research use but also on the capabilities of this type of particle beam pulse experimentally generated on other accelerators. Moreover, accelerators for experimental use are also test platforms which answer a number of even more difficult questions--for example, are particle beams capable of satisfactorily penetrating the air and outer space, and, in conjunction with that, precisely hitting military targets? The Livermore advanced test accelerator (ATA) is primarily used in order to study problems of transmission of charged particle beams in the atmosphere. The thrust of the Los Alamos "White Horse" project, by contrast, is to study how to produce a type of neutral particle beam, making it capable of transmission in outer space over adequately long distances.

Mutual coulomb force effects will be felt between the particles of charged particle beams. Similar electric charges will repel each other. However, when electric charges are flowing in the same direction, they will produce a magnetic field surrounding the beam itself. It plays the role of squeezing together the beam. This type of autoconstriction effect can be observed when strong particle beams pass through the air. In this situation, autocontraction forces make beam diameters shrink to under 1 centimeter.

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Air will cause particle beam directions to deflect. Moreover, it constantly absorbs the energy of the particle beam. Under normal conditions, electron beams are capable of flying

approximately 200 meters before half their energy is absorbed by the atmosphere. Speaking in terms of single pulses, this then limits the effective range of weapons. However, in tests, this kind of situation appeared. Within approximately 10^{-6} seconds, the air heated by the first pulse will produce thermal expansion providing a path for the second pulse. As far as theoretical predictions are concerned, this type of "aperture" effect is capable of allowing beams to be transmitted several hundred kilometers.

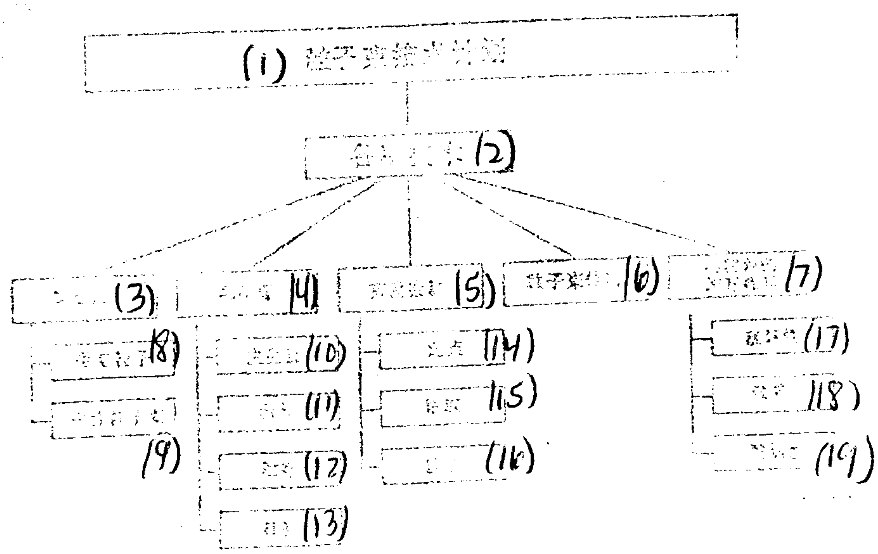

Fig.7-6 Principal Constituent Parts of U.S. Defense Department Recognized Particle Beam Plans. Accelerators take particles and accelerate them to high (illegible) and high energies. Power sources supply energy needed by accelerators. Beam controls include particle (illegible), particle beam transmission (refers to particle beams reaching targets through the atmosphere and space), and the mutual effects of materials including phenomena produced by particle beams hitting targets.

Key: (1) Particle Beam Technology Plan (2) Technology Items (3) (Illegible) (4) (Illegible) (5) (Illegible) Control (6) Particle Beam Transmission (7) Mutual Effects With Materials (8) Charged Particles (9) Neutral Particle Beams (10) Generator (11) (Illegible) (12) Storage (13) (Illegible) (14) Fixing (15) (Illegible) (16) (Illegible) (17) Destructiveness (18) Effects (19) Fragility

Livermore's advanced test accelerator is used in order to supply high strength particle flows to facilitate the experimental demonstration of theoretical predictions. In accordance with Defense Advanced Research Planning Agency concepts: ATA test parameters must be larger than the extremely small values required by stable electron beam transmission at atmospheric densities. Initial tests empirically verified transmission modes appropriate to the carrying out of range tests. In experiments after that, beam parameters were changed in order to facilitate the carrying out of evaluations of acceptable ranges during actual explosions in transmission modes. /150

Taking Pentagon official jargon and putting it somewhat more colloquially, the tests were in order to observe whether or not electron beams are able to penetrate several kilometers of atmosphere in order to destroy military targets.

7-4 Neutral Particle Beams Used in Missile Defense

Very clearly, charged particle beams are not appropriate for transmission to places several thousand kilometers distant in order to destroy military targets--enemy missiles. Because of mutual repulsion between particles carrying the same electric charge, beams are made to diverge. At the same time, geomagnetic fields also make beams deflect in directions difficult to predict. Moreover, in outer space, changes in transmission path will cause very strong applied forces to block beam transmission. These problems can be avoided through utilizing neutral beams. At the Los Alamos Defense Advanced Research Planning Agency "White Horse" project, empirical verification of this plan is in the midst of being carried out. However, accelerators are only capable of accelerating charged particles. They cannot accelerate neutral particles. As a result, how to produce high energy neutral particle beams is a key question. The methods

used at Los Alamos are, first of all, to make hydrogen atoms carry a negative charge, that is, two electrons circling around a proton and not the normal one electron circling around one proton. After taking them and accelerating them to high energies, they are made to go through gases or certain other such media, stripping off excess electrons and turning them into neutral particles.

In outer space, there are no obstacles blocking neutral particle beams. At the same time, neutral particles are not influenced by geomagnetic fields. Once beam paths are determined, particles then move along a straight line right up to a certain object (may possibly be the target) which blocks them and they stop. They are not like photons which have no mass. The earth's gravitational field will produce influences on neutral particles with very large masses. However, speaking in terms of particle beams associated with movement close to the speed of light, these influences are very small. At the same time, they are very easily calculated (see Fig.7-7). /151

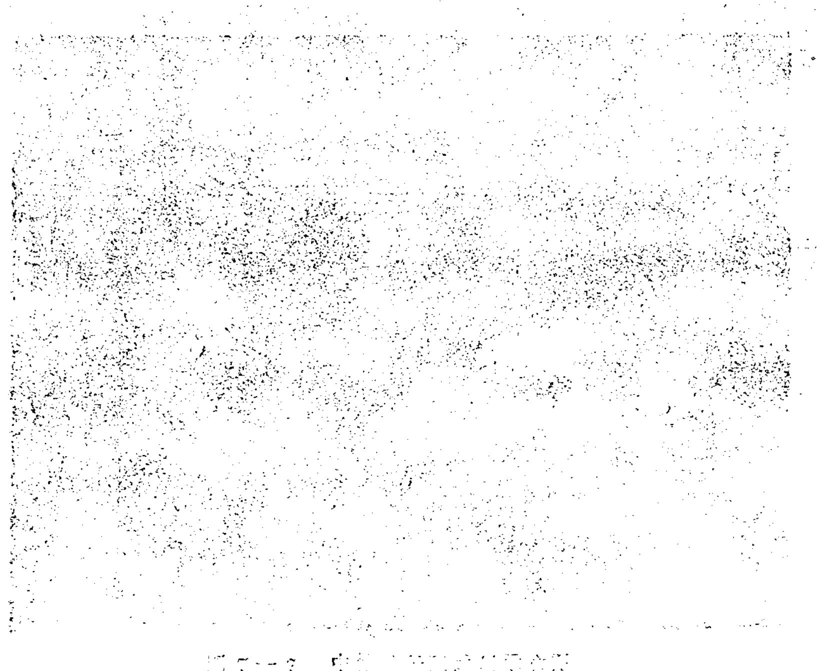

Fig.7-7 Neutral Particle Beam Weapon Schematic

Los Alamos is just in the midst of exerting its efforts on resolving production and transmission problems influencing beams. Speaking in terms of words used in Defense Advanced Research Planning Agency plans: "The key problem associated with neutral particle beam systems is the need to successfully develop system components having a decisive significance on final beam divergences. Only in this way is it possible to have maximum range." If one wants to obtain a narrow neutral beam which is capable of traveling long distances and not diverging, it is necessary to resolve the questions discussed below: finding some method to strip off excess electrons associated with negative hydrogen ions and not influencing the quality of beams. At the present time this problem is still not resolved. Beam quality can be influenced by many types of factors. When taking away excess electrons, even if only slight scattering is given rise to, it is still sufficient to cause neutral beams to produce deflections when hitting targets over several hundred kilometers away. At the same time, scattering of this kind will also cause beam divergence, create power density drops, and lead to an inability to damage targets when arriving at them. Scattering also causes particle beam energy divergence. During particle beam transmission, this effect will cause beam lengths to increase. Because--following transmission distance increases--beam speed divergences also increase, during transmission, the spacial arrangement then becomes longer and longer. This type of situation makes military people's interest in high power pulse neutral beams drop greatly.

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Besides the two primary purposes raised before, the Defense Advanced Research Planning Agency also initiated the development of so called "basic technology". The purpose is to obtain more accurate knowledge in order to satisfy weapon requirements (or it is to obtain a confirmed answer that it is not possible to use something in the weapons area).

Due to the fact that neutral particle beams will generate ions and charged particles when they pass through the atmosphere, as a result, they can only be installed in outer space. They can also only be used in attacking space targets. If this type of weapon can be miniaturized, it is then possible to place it on the ground. Once required, it can then be immediately launched into outer space.

Neutral particle beam weapons are composed of negative ion sources, particle accelerators, magnetic beam focusing and guiding heads, stripping systems, electricity sources, as well as other auxiliary equipment. As far as these components are concerned, it is possible to make use of similar components installed at the present time to use for other purposes. If the scale of the use is not too great, it is then possible to supply a certain antisatellite capability. For example, hydrogen atoms produced by an accelerator associated with the Los Alamos meson physics plant have energies of 800 mega electron volts and are capable of penetrating one meter thick lead shielding layers. This accelerator is capable of producing hydrogen atom beams associated with currents of 1 milliampere. Using it to fire at an unhardened satellite over 40 thousand kilometers away, in a period of a few minutes, it is then capable of destroying the satellite's electronic circuits.

A neutral particle beam weapon propelled by a turbine motor requires an approximate total weight of 25 tons of liquid hydrogen and liquid oxygen (including containers and other frame weights) in order to facilitate the application on targets over 40 thousand kilometers away of 10 thousand Gray doses of radiation (The Gray is an international unit of absorption of radiation energy. 1 Gray is the dose of radiation when each kilogram of material absorbs 1 Joule of radiation energy or is equal to 100 Rutherfords. 100 Grays is one tenth of a mega Rutherford). As far as absorbing ten thousand Gray doses of

radiation is concerned, with regard to most radiation resistant high density silicon integrated circuits, a good number of space craft, and high density integrated circuits which will be going into use--both currently existing and planned for manufacture--it is fatal. The reason is that their radiation resistance strengths are 3-4 orders of magnitude lower than the doses in question. If one wants to destroy, at this range, electric circuits which are able to withstand 100 thousand Grays, it is then necessary to take neutral beam weapon transmission powers and raise them 10 fold, that is, there is a need for the equivalent of 250 tons of liquid hydrogen and liquid oxygen and only then is it possible to reach this target. With regard to the same kind of circuit at 1000 kilometer ranges, the equivalent weights of liquid hydrogen and liquid oxygen required for destruction doses are only 1.6 tons. With regard to a currently existing 1000 kilometer range integrated circuit, 1 kg of equivalent weight is adequate to destroy it.

Despite the fact that hardened high density electronic circuits are capable of withstanding radiation doses with strengths of 10 thousand Grays and will not show permanent damage, the requirement, however, for all satellites to be capable of hardening to this type of level is not realistic. In situations where radiation strengths are a few orders of magnitude lower, speaking in terms of instantaneous losses of efficiency in electronic circuits with regard to computers, it is possible to give rise to losses of memory capabilities. As a result, neutral particle beam weapons are not only capable of use in offensives against satellites. They are also capable of use in attacks on false targets. At this time, it is only necessary to use unusually small amounts of fuel and auxiliary structure (the total weight is approximately 250 kg). This is then adequate to apply 10 Gray radiation doses to targets at ranges of 40 thousand kilometers.

Based on estimates, with regard to neutral particle beam weapons, the total weight of fuel and auxiliary equipment required for each megawatt of power is approximately 4 tons. When carrying adequate fuel, there is an approximate capability for 1000 seconds of operation. The U.S. space shuttle or the corresponding Soviet space plane are roughly capable of taking 30 tons of neutral particle beam weapon and installing it low earth orbit (see Fig.7-8). Soviet high thrust launch rockets are capable of taking 150 tons of effective load and sending it into low earth orbit.

If one wishes to make neutral particle beams capable of effectively hitting targets, it is necessary to make neutral beam divergence angles small in order to guarantee very small beam spots on distant targets. For example, on targets at distances of 40 thousand kilometers, one must take beam diameters and limit them to within 40 meters. It is then necessary to have good target aiming capabilities. Degrees of precision should reach 1 micro radian. This type of requirement--speaking in terms of neutral particle beams--will be much more difficult than /154
using continuous wave lasers or repeating (illegible) pulse lasers. Laser aiming and tracking systems are capable of very quickly determining from light beams reflected from targets whether or not beams hit targets. However, when targets undergo neutral particle beam hits, secondary radiation will be produced. Within a range of 100 kilometers around targets, it is possible to probe for and get X rays, γ rays, and other rays. As a result, it is very difficult to also sensitively probe for target movements.

Neutral particle beam weapons are capable of being assisted by long wave infrared rays in probing for targets. In conjunction with this, relying on flexible "vision" systems /155
in order to track targets, they are also capable of accurately determining target firing angles on the basis of information

provided by tracking systems. However, it is only possible to guarantee that tracking systems are pointed toward targets. In conjunction with this, it is certainly not possible to completely guarantee that neutral particle beams are fired toward targets.

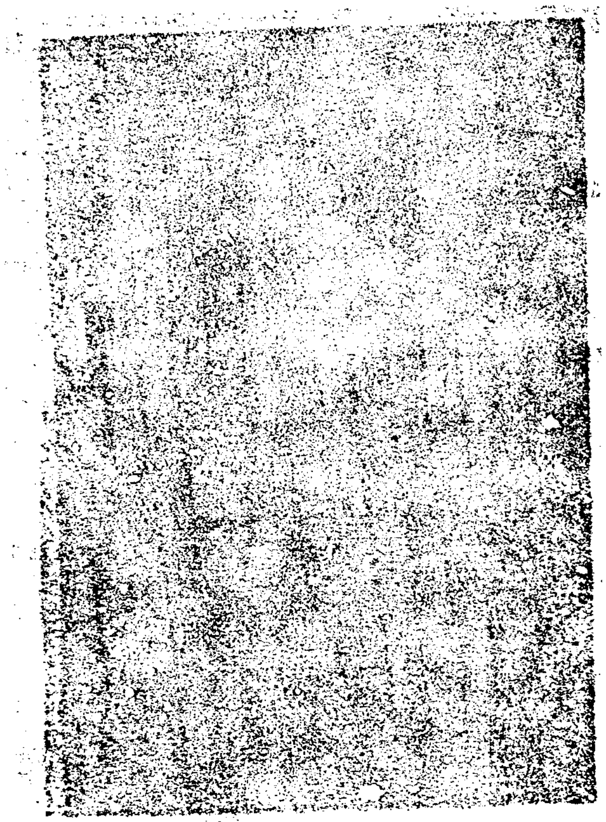

Fig.7-8 Sketch of a Space Shuttle in the Midst of Placing a Neutral Particle Beam Device

7-5 Soviet Particle Beam Technology

The U.S. side knows that the Soviets have big plans in the area of particle beam technology. However, there is certainly no precise understanding of these. Starting out from the requirements of basic scientific research, the main applications of particle beams are in subatomic physics. Therefore, normally, they are regarded as harmless "inactive subject" fields. The U.S. and the Soviets are not only both openly exchanging their various individual viewpoints. There are, moreover, a number of scholarly products which have been openly published in scientific

magazines. What is even more meaningful is that the U.S. is currently engaged in a large number of related experiments and theoretical work which originated ultimately in the Soviet Union.

Pentagon officials seem to have complicated feelings about Soviet plans. In early 1982, in reports published relating to particle beam projects, it was said: "In accordance with assessments, the Soviets have much greater strength than the U.S. (in particular, in the realm of accelerators used in fusion research). Moreover, they have already made great progress. However, reports associated with the Soviets concerned taking particle beams and work related to weapons and putting them together have not as yet been seen." The U.S. Defense Department, in the latter part of 1981, published a pamphlet related to "Soviet Military Power". It said: "The Soviets, beginning in the early 1950's, have been interested right along in the idea of particle beam weapons (PBM). In the Soviet Union, technological fields relating to particle beam weapons have been confirmed as having unusually outstanding areas."

"Aviation Week and Space Technology" magazine has published many suggestive articles. Military editor Lubinxun (phonetic), in his first article relating to this area, has bluntly said: "The Soviets are just in the midst of developing charged particle beam weapons. In conjunction with this, they are attempting to use them in order to destroy U.S. ICBM's and strategic missile warheads launched from under water. Experimental research is being carried out at a certain place in Soviet Asia." In the middle of 1980, the magazine in question published another article announcing: "The first step in transforming revolutionary directed energy weapons--weapons systems----in the midst of being carried out in Soviet Salishagan (phonetic)..... Many U.S. intelligence analysts believe that these weapons are nothing else than new designs associated with embryonic models of charged particle beam systems. Within a year more or less, these

may then be capable of being used in order to carry out antiballistic missile tests." In this article, there was no description of the status of tests at that time. Other magazines were also like this.

Although Soviet military plans are secret from the West, openly published Soviet scientific magazines, however, almost unquestionably showed that clearly the Soviet Union had expended very large efforts in the technological areas of pulse power and particle beam production. Based on summaries associated with Soviet scientific magazines published in 1962-1976, in a 1978 Rand Corporation report, it was written: "The scale of the Soviets in the area of pulse power research and development seems to vastly exceed what is talked about in the open. The objective lies in transforming to a scale required by controled thermonuclear reaction energies." The report in question brought up the fact that work in the area of applications of pulse power in open Soviet reports were "unusually confused and unclear". Despite the fact that the reports in question refused to explain efforts to study the area of particle beam weapons on the Soviet side, it still, however, drew the conclusion: "It is very possible that the Soviet Union has already done this."

7-6 Beam Control Problems

Similar to high power lasers, the construction of a large particle beam generator itself is much easier than using the system in question for certain military purposes. At the present time, the Pentagon is in the midst of concentrating its /157 objectives on making particle beams penetrate air or outer space and hit targets. It is possible to foresee that there is still a big difficulty existing here--beam control, that is, making particle beams aim at targets and, in conjunction with that, track targets. Theoretically speaking, what seems to be needed

is simply--after beams are produced from inside accelerators--to add a certain electric field and (or) magnetic field to deflect them in just the same way as magnetic fields make electron beams deflect inside television picture tubes. However, if one wishes to use this type of idea in applications to reality, it is then not that easy to do.

In Pentagon reports relating to particle beam technology, it is written: "No matter whether it is with regard to charged particle beams or neutral particle beams, beam control sections, in all cases, are the most key technologies. They exceed current technological levels. Moreover, at the present time, there is no technological foundation."

The degree of difficulty associated with beam weapons in applications depends on the nature of the mission. In the latter part of the 1970's, the Pentagon got four different concepts from research on particle beams.

(I) Short Range Weapons Utilization is made of secondary high energy radiation of very short wave length produced when particles in strongly charged particle beams and air molecules (atoms) collide. This type of secondary radiation forms a circular cone shape. Added together with charged particles, X rays, and ■ rays, it is capable of destroying military electronic equipment and killing and wounding soldiers. Within a range of approximately 1 kilometer, a high radiation dose is formed, and there is a lethal belt shaped zone. In this type of situation, there is no need to accurately aim and track.

(II) Medium Range Weapons This type of weapon is used in the atmosphere. Because well directed and focused particle beams must penetrate at least 5 kilometers, and, only then is it possible to destroy such hardened targets as nuclear missile warheads, it is, therefore necessary to precisely aim and track.

(III) Long Range Atmospheric Weapons These use well focused charged particle beams to destroy targets beyond 10 kilometers. These then require even higher pulse energies and even more accurate aiming and tracking.

(IV) Space Based Neutral Particle Beam Weapons In order to defend against ballistic missile attacks, it requires particle beams to have several hundred or several thousand kilometers range. Hitting missiles this far away will require particularly accurate aiming and tracking systems.

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Some particle beam weapon critics believe that the problems of directing are the most key problems. A research team associated with the (illegible) engineering institute put forward the conclusion: "Among beam weapons, whether or not beam ignition and control systems are technologically feasible is still worthy of suspicion." Despite the fact that some people are very optimistic, most observers, however, believe that this problem is not so simple.

7-7 Hitting Targets

As far as very well focused particle beams hitting targets is concerned, they are capable of giving rise to very great damage. Within targets, ion beams penetrate a narrow cone shaped path, accumulating approximately 106 Joules of energy, and giving rise to huge destruction. In aluminum, high energy electron beams are capable of penetrating several hundred centimeters. Their destructive effects far, far exceed the defensive capabilities of fast moving targets. Particle beam effects are capable of giving rise to the several types of consequences below: rocket fuel (illegible) explosions create structural destruction, electronic equipment malfunctions, high energy secondary radiation produced by beam and target effects severely

damage electronic equipment. The majority of military analysts believe that, if particle beams penetrate deeply, then any target will be unable to avoid meeting destruction.

Despite the fact that destruction brought by secondary radiation and particle beam diffusion are different, their radiation on electronic equipment associated with weapons, however, is also capable of bringing lethal damage to weapons capabilities. However, due to beam strengths being very low, destruction given rise to in the structural area is very small or basically just not detectable. Like other "silent" casualty (illegible), the damage produced by them cannot be seen. As a result, weapon users will (illegible).

7-8 Problems of Feasibility

When talking about particle beam weapon feasibility, one must first of all answer some other important questions primarily concentrated in the areas of enormous particle beam production equipment and power systems. One sarcastic person said: "The only way laser weapons kill people is to take the laser and hit the person with it." This saying is perhaps even more /159 appropriate speaking in terms of particle beam weapons. In accordance with the current level of technology, they are much bulkier than chemical lasers.

However, particle beam weapons have indisputable attractions. At least theoretically, particle beam generators are capable of continuous rapid firing. Moreover, a single shot is capable of destroying targets. If beam production equipment and ignition and control systems are capable of very good operation, beam weapons are capable of shooting scores of targets each second. This type of attack capability will be one the "Death Star" designers in the movie "Star Wars" would envy.

Besides test cancellations coming from Livermore and Los Alamos and making people unhappy, in the next few years, debates will continue right on relating to particle beam weapons feasibility. In 1983, the Pentagon only spent 50 million U.S. dollars on particle beam weapons (accounting for 10% of the directed energy budget). This reflects (illegible) serious Pentagon considerations of the difficulties confronted in this problem and also deliberations on the application outlook for particle beam weapons. In the minds of Pentagon policy officials, particle beam technology is even less mature than laser technology. Of course, time will ultimately tell people what selection should be made.

7-9 Exploration of New Particle Accelerator Principles

Following along with our deepening knowledge of the natural world and the development of particle physics, there is a need to have ultra high energy particles to use in research and applications. However, conventional particle acceleration technology seems to have already reached its proper limits. The several highest energy accelerators which are just under construction are like this--for example, the western European research center's large model electron--positron collider (LEP) and the proposed U.S. superconducting supercollider (SSC). The superconducting supercollider's acceleration ring diameter reaches 60 kilometers. The investment is approximately 3 billion dollars. The size of the scale and the huge costs both are startling. Even if use is made of superconducting magnets and superconducting high frequency cavities, it is still not possible to change this type of situation. As a result, how to make use of new technologies and new principles in order to accelerate charged particles, lower construction costs, and shrink bulk is a pressing subject. Laser acceleration and trailing fields as well as two beam acceleration technology concepts have given people hope.

I. Laser Acceleration Concepts /160

Laser acceleration includes the three types of proximate field models, distant field models, and plasma models.

Proximate field accelerators are miniatures of open type linear accelerator structures. They maintain lengthwise acceleration field components (non planar waves). The feasibility of open type linear accelerator structures formed from liquid metal micro particles is in the midst of study. In this structure, maximum acceleration gradients associated with liquid (illegible) turned into plasma are capable of reaching 1 GV/m (1GV=109 volts).

In distant field accelerators, particles are shaken in crosswise movements in order to facilitate isochronous acceleration in effects associated with going through a planar

laser wave alternating crosswise electric field. The main design is the anti free electron laser model. Electrons pass through a series of alternating static magnetic fields (not yet modulated) and shake. The acceleration gradients associated with the accelerators in question are smaller than a few hundred mega electron volts / meter. Due to radiation losses associated with synchronous accelerators, the maximum energies do not exceed a few hundred GeV.

The concept of plasma--laser accelerators (that is, beat frequency plasma accelerators) has already been set out as an independent plan. The basic principle is that extremely high electric fields possessed by modulated high density plasma waves are used in order to accelerate ions. Moreover, beat frequencies associated with two coherent laser beams are used in order to drive high density plasma. With regard to this type of

acceleration method, large amounts of analysis and numerical simulation calculations have already been done.

II. Simple Tentative Plan for Two Beam Accelerators

In two beam accelerators, use is made of an electric field (trailing field) produced by low energy high flux beams in order to accelerate another beam to high energy. Two beams are transmitted in the same accelerator structure. Fields are transmitted from an empty cavity to a coupling device, or two beams are transmitted in the same cavity. /161

Besides this, as far as the acceleration principle of making use of strong electron beam collective fields to accelerate ion groups is concerned, exploratory tests are also being carried out at a number of laboratories.

Exploration of new accelerator ideas will make accelerators develop toward high strengths, high gradients, and miniaturization. It not only opens up broad prospects for high energy physics and particle physics. It also provides lessons for the development of particle beam weapons. New particle accelerator principles are an entirely new field, involving relatively numerous subjects. It has already passed beyond the scope of this book's discussions. Interested readers can consult the relevant references.

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7-10 Electromagnetic Guns

Besides tentative plans for methods to destroy targets with beam weapons based on nuclear explosions and sensitive to the atmosphere, the U.S. strategic defense initiative agency also produced strong interest in electromagnetic guns.

Compared to chemical guns, electromagnetic guns eliminated the inherent limitations associated with chemical combustion launching systems. For example, the pressures which chemical gun tubes can withstand keep the weights of projectiles from exceeding 100 kg. Besides this, the speeds of expanding gases keep the speeds of shells fired from inside single stage chemical guns from exceeding two kilometers a second.

Rockets do not suffer from the speed limitations of expanding gases. As long as it is possible to spray out material, it is then possible to acquire momentum. However, the huge dead weights of rockets severely influence their efficiencies. Dead weight generally includes rocket motors and fuel weight. The dead weights of certain rockets are capable of reaching 130 times useful load. Conversely, what electromagnetic accelerators fire is almost completely useful load.

There are two types of electromagnetic guns currently in the midst of development: rail guns and induction guns.

Australia National University's Richard A. Maxieer (phonetic) is the forerunner in developing rail guns. The rail guns he developed were composed of two parallel steel rails and a projectile. The projectile is generally a sliding block and electric brushes. This projectile forms a lone electric /162 connection between the two rails. After that, electric current follows the other rail and flows back. The current between the

two rails produces a magnetic field perpendicular to the plane of the two rails. On the basis of Lorentz force equations, the magnetic field and the electric current flowing through the projectile mutually effect each other thus causing the projectile to accelerate along the rails (see Fig.7-9). /163

Maxieer (phonetic) and his colleaques, in the early 1970's, carried out a large scale test on rail guns. They made use of a huge generator over two stories high and capable of producing 1 million 600 thousand ampere currents. It was capable of taking a 3 gram mass square block, and, on five meter rails, accelerate it to speeds of 6 kilometers per second. The acceleration was equivalent to 3.6x10^(illegible) g (g is the acceleration of gravity on the earth's surface).

U.S. "Star Wars" advocates, with regard to the rail gun, had the idea that it was adequate to use large strong currents of 1-2 million amperes and accelerate shells to speeds of 25-30 kilometers per second. Taking 100 of this type of rail gun and deploying them in orbit 2000 kilometers from the earth's surface, once they received commands, they would then be capable of firing over five hundred plastic shells weighing two kilograms within two minutes, destroying the over 1000 ICBM's the Soviet Union is capable of launching in the ascent phase.

However, there is still a very great distance between current real levels and the ideas of the U.S. "Star Wars" strategists. Moreover, there are still a number of technological problems awaiting solution. First of all, in a system large enough to be able to take actual useful loads and be launched into orbit or be able to fire antiballistic missile projectiles, the rails must withstand explosive magnetic forces. This type of explosive force is similar to gas pressure effects in gun tubes. Second, if gun lengths increase, then, energy lost in thermal radiation and track magnetic fields also then increases. Due to

the fact that actual rail gun lengths reach several meters or even longer, these problems are then very difficult to resolve. If one takes rails and divides them into several sections, and each section is connected to its own power source, then, it is possible to resolve the problems in question. However, rail guns require very large electric currents and very low voltages. Obviously, this type of advanced method is very difficult to realize.

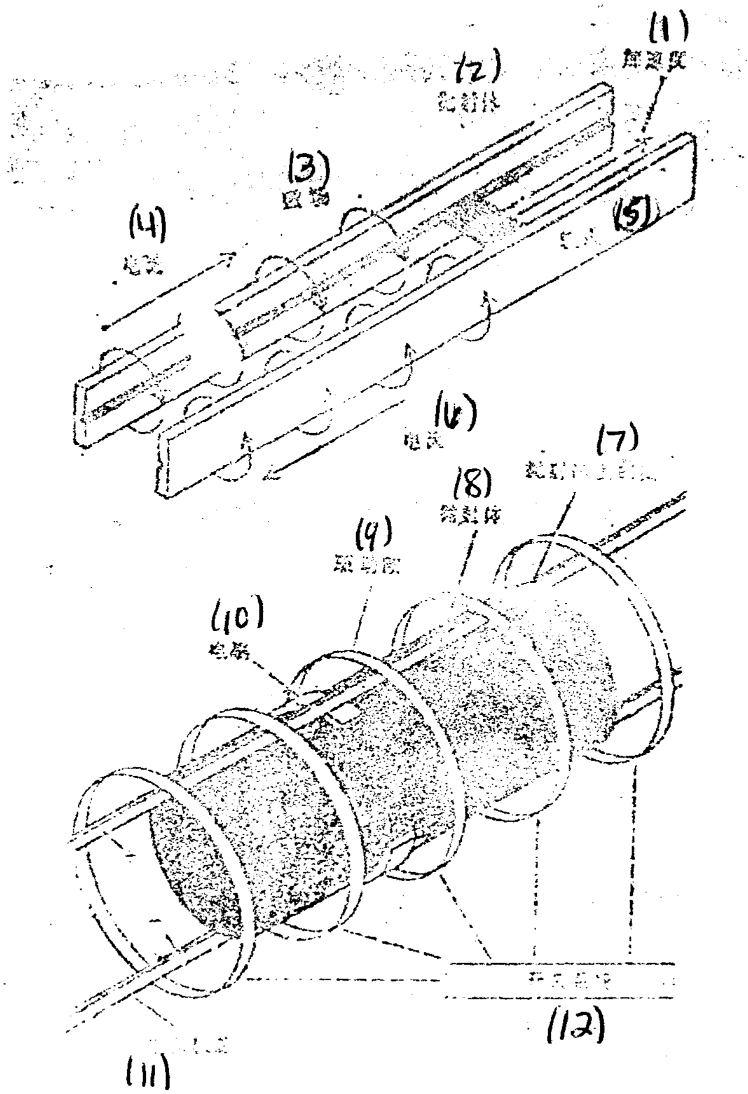

Fig.7-9 Rail Gun (Top) and Induction Gun (Bottom) Schematics

Key: (1) Acceleration (2) Projectile (3) Magnetic Field
(4) Electric Current (5) Rail (6) Electric Current
(7) (Illegible) on Projectile (8) Projectile (9) Drive Ring
(10) Electric Brush (11) Electric (Illegible) Rail
(12) Switch System

Induction guns are one type of substitute plan for rail guns. During the period of operations at Masheng (phonetic) science and engineering institute, Henry H. Kemu (phonetic) and Peter Maaier (phonetic) promoted development work on induction guns.

Induction guns are composed of a set of fixed drive rings. A barrel shaped projectile is (illegible) moved within the drive ring cavity. One or a number of rings are attached to projectile surfaces. These rings pass through electric brushes connected to power source rails and bring in current. They are also capable of producing electric current through electromagnetic induction. In these two types of situations, there will be a stable magnetic field around the projectile in question in all cases. In order to make this projectile accelerate, the direction of current within drive rings must change back and forth in order to /164 facilitate the projectile's being drawn toward the forward drive ring and pushed forward, at the same time, by the rear drive ring. The current within drive rings must be synchronized with the movement of the projectile, that is, only when projectiles approach or leave a certain drive ring does current then flow to the drive ring in question. Induction guns are superior to but more complicated than rail guns. Their complexity brings with it several problems which are difficult to resolve--for example, when projectile speeds exceed 10 kilometers per second, it is possible for projectile rings to melt.

At the present time, maximum accelerations obtained by the use of electromagnetic launchers have already reached 2 hundred million g (g is the acceleration of gravity). This is eqivalent to taking a projectile in a state of rest and accelerating it to speeds of 5 kilometers per second in a distance of two centimeters. In experiments, the maximum mass which has already been launched to high speeds is 330 grams (approximately 2/3 of a pound). Rail guns are capable of taking this projectile and

accelerating it to a terminal velocity of 4.3 kilometers per second. Used as antimissile systems, rail guns or induction guns must make projectiles successfully pass through 1000 kilometer engagement distances. Full development of rail guns and induction guns seems still very far from the objectives in question (see Fig.7-10).

Although a number of key technology problems exist with regard to electromagnetic guns, their development potential, however, is not easy to doubt. Following along with the full speed development associated with current cutting edge technology--particularly, superconductor technology--people's interest in electromagnetic guns grows stronger and stronger.

This can be seen from nothing else than the serious attention the U.S. gives superconductor materials. The reason is that, if superconducting technology can be applied very well to electromagnetic guns, then the difficulties associated with high currents and low voltages will be resolved. The U.S. Defense Advanced Research Planning Agency chief Keleige Feierci (phonetic) said that the agency in question has already taken large amounts of funding and approriated them at the present time to 6 ceramics supply companies for use in research on methods to produce superconducting materials. This agency also signed /165 contracts with 6 other companies to carry out joint explorations, and, in conjunction with this, is going through the Navy to begin "an important new procurement activity". In fiscal year 1988, beginning 1 October 1987, this superconductor development plan will spend several tens of millions of U.S. dollars.

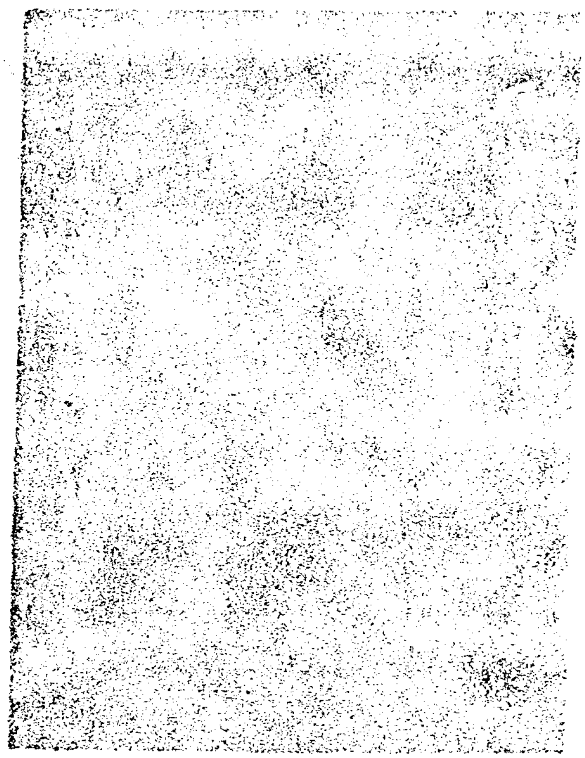

Fig.7-10 Westinghouse Company's EMACK Electromagnetic Launcher During Installation and Tests

Chapter VIII HIGH POWERED MICROWAVE

Microwaves also belong to electromagnetic radiation. Their wave length is normally on the order of (illegible)meters, longer than the wave lengths of both visible light and infrared light. People's research with regard to this type of microwave electromagnetic radiation began development relatively early. Moreover, in the area of applications, it has also already achieved accomplishments in a number of areas.

The original driving force in microwave research came from military applications--for example, radar, already occupying a conspicuous position in military equipment. The principle for its operation is to send out microwave beams toward the heavens and carry out scanning, at the same time, receiving microwave signals reflected back from objects in the sky. Finally, imagery signals are obtained of heavenly objects from the returned signals.

Here we introduce what are called stealth aircraft. Stealth aircraft are a type of new model aircraft used to cope with enemy radars and are not discovered by them. Through the addition to the surface of the aircraft of a material which is capable of intensely absorbing microwaves, the microwave beams which radars emit are made to be absorbed by this type of material, and they do not produce reflection signals. This type of aircraft is then capable of "disappearing" on radar. For example, the U.S. B-1 strategic bomber is just such a stealth aircraft in active service.

Due to impetus from the military, microwave source technology development is very rapid. In the middle part of the (illegible) decade, the power of 10 centimeter wave length microwave sources already reached several hundred kilowatts.

Following this, because microwave source transmission powers follow along with increases in frequency (wave length reductions) and decrease, but the shorter microwave wave lengths are, the stronger is the resolution (illegible) with regard to objects in space, therefore, engineers then directed their efforts toward realizing relatively short wave length, high power microwaves. Applications to military technology of millimeter wave high power generators are (illegible) problems awaiting solution.

Microwave communications have already become a relatively mature communications form. Following along with this, (illegible) wave propogation characteristics in space were studied in depth. Microwave communications technology achieved rapid development. At the present time--in the same way as radio communications--microwave communications have already (illegible) very much. /167

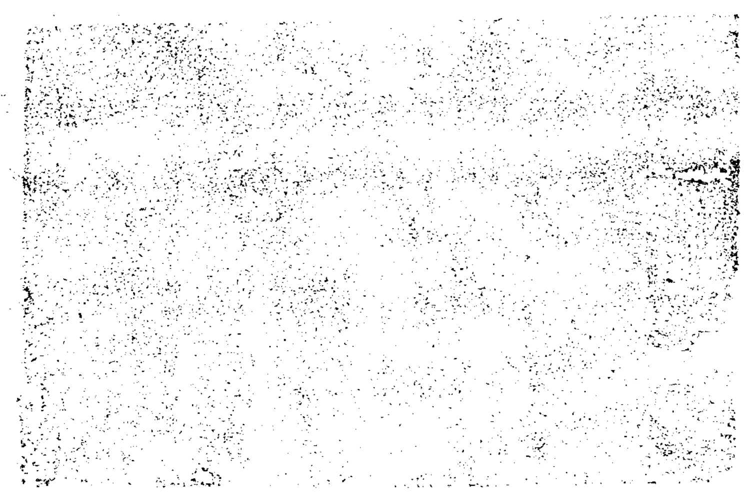

Fig.8-1 Schematic of a Type of (Illegible) Model (Illegible) Radar. This is a part of an antiballistic missile system developed by the Soviet Union to use to defend Moscow. Radar construction (illegible) associated with (illegible) structure is approximately 35 meters high and 150 meters (illebible).

Microwaves have one very conspicuous characteristic. This is nothing else than the thermal effects associated with microwaves. When microwaves are fired toward objects, part of the microwaves will be absorbed causing the objects to heat up. Microwave ovens are one very clear example of exactly this. Taking food and putting it into a microwave oven, microwaves are capable of making the food change from raw to cooked. However, people standing beside the oven still feel no bad sensations. A number of people find this mystifying, even to the point of being afraid. It was precisely due to this type of fear psychology that an intense interest was produced in a number of military personnel. Some people (illegible) said, anything that is capable of making the masses afraid will then generate interest in the military.

8-1 Microwave Effects

People have already achieved a relatively clear understanding of the thermal effects of microwaves. When /168 microwaves are utilized as weapons, damage effects created on targets are similar to heating processes. In all cases, this is due to the fact that objects absorb large amounts of microwave energy. Microwaves are capable of producing different types of military application results.

-----When microwave power emited by microwave weapons very greatly exceeds limit values which are associated with signals which antennas are capable of receiving, they will then cause microwave radars and microwave communications systems to give rise to blockages. This type of effect is similar to very strong static electrical interference in AM radio communications signals. Power densities at this time are 10^{-8} - $10^{(\text{illeg.})}$ watts/cm^2.

-----Using pick ups associated with distant microwave power transmission or other equipment, it is possible to cause normal operations without the need for electric power source lines or internal electric power sources. Generally, this requires powers of 0.01 - 0.1 watts/cm^2 . There are people who have brought up the idea of a type of solar energy satellite power station, that is, building a solar energy power station on a geostationary satellite, and transmiting the energy down in the form of microwaves. On the earth's surface, then receive them through antennas (see Fig.8-2).

-----Strong microwave beams, in electronic equipment or pick ups, are capable of giving rise to microwave electric currents. Moreover, microwave electric currents are also capable of submerging the signals in them and causing interruptions in their operation (This is distinguished from blocking effects. Blocking effects are aimed at equipment associated with receiving microwave signals.). The powers required in this type of situation are very high--approximately 10-100 watts/cm^2.

-----Within quite a short period of time, utilizing the same effects as microwave ovens to heat targets thereby producing damage in them. The powers required for this are even higher. Normally, they are 1000-10000 watts/cm^2.

As far as microwave effects on targets are concerned, besides being related to power magnitudes, they are also related to the properties of targets. In particular, there are relationships with target surface properties. Generally, most target object outer shells are metal. Due to the fact that metal capabilities to reflect microwaves are very strong, as a result, damage received by target objects is then small. This (illegible) a shield. Conversely, materials absorbing microwaves, by contrast, strenghten the efficiency of microwave

effects--for example, stealth aircraft which are difficult to discover on radar are then easily damaged.

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Microwave thermal effects should be valid in the same way on human bodies. Because the human body, in its chemical structure, is similar to the food in a microwave oven, as a result, under the effects of very high microwave powers, people cannot survive.

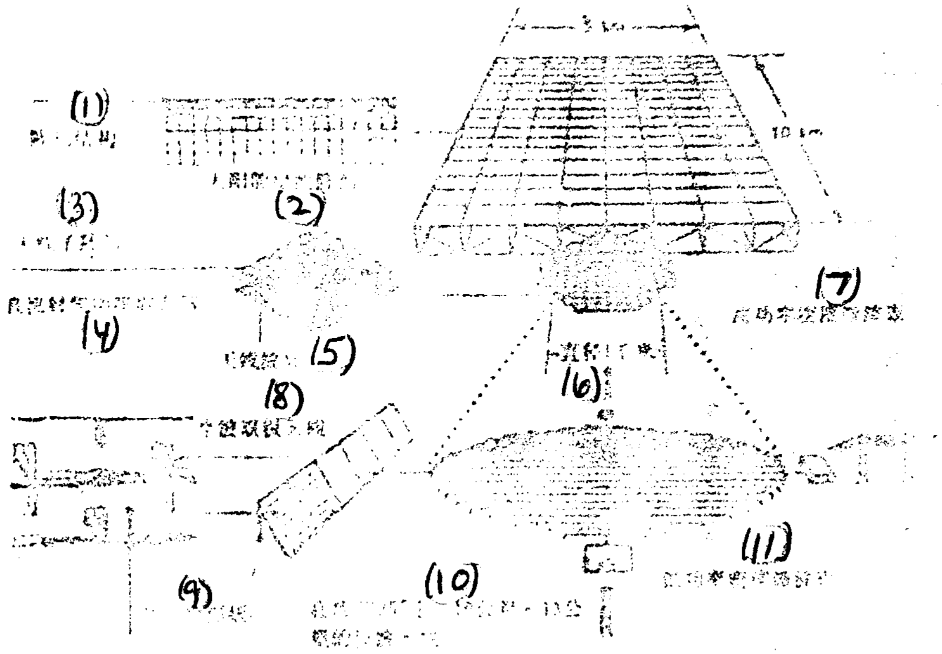

Fig.8-2 Primary Components of a Solar Energy Satellite System (Using Microwave Transmission) Supported by the U.S. Department of Energy and NASA. The upper right solar energy electric (illegible) takes solar energy and turns it into induced electrical energy. This (illegible) electric energy goes through a 1000 meter diameter satellite receiving atenna in order to (illegible) on earth. An (illegible) antenna capable of covering a medium sized city also takes (illegible) electric power. Ionosphere (illegible) will (illegible) microwave transmission (illegible) power densities.

Key: (1) Array (Illegible) Structure (2) People (Illegible) Electric (Illegible) Array (3) Antenna Sub (Illegible) Array (4) Linear (Illegible) Emission (Illegible) Power Amplifier (5) Antenna Discharge (Illegible) (6) 1000 Meter Diameter (7) (Illegible) Power Density (Illegible) (8) (Illegible) Antenna (9) (Illegible) (10) At (Illegible) 35°, 10 km x 13 km (Illegible) Antenna (11) Low Power Density (Illegible) Beam

Besides this, even if they are low power microwaves, irradiation over long periods will also produce a certain harm in human bodies. Research personnel discovered that, if people were put under long term microwave irradiation of (illegible) 0.1 /170 watts/cm^2, it can lead to cataracts. Human body tissues will also produce very great (illegible) thermal damage. However, this power density is far lower than power levels in microwave ovens. (Illegible) power densities lowered to 0.001 watts/cm^2, it is still not possible to (illegible) the harmful effects.

As far as only overly large microwave powers producing clearly harmful effects on human bodies is concerned, at the present time, this question has still not been consistently resolved. Allowable microwave dose standards set by various countries are different.

8-2 Microwave Weapons

With regard to microwaves functioning as directed energy weapons, the (illegible) lies in microwave sources going to be much cheaper than lasers. 1 thousand watt microwave tubes can be produced in batches at 50 U.S. dollars a piece. However, the construction cost of one high power carbon dioxide laser will be a number of fold higher than this, and batch production is not possible. Besides this, developments in radar technology and communications technology have also laid a firm foundation for the development of microwave weapons.

Of course, a number of weak points also exist with microwave weapons. One very striking point is nothing else than their bad direction and focusing capabilities (see Fig.8-3). On the basis of diffraction principles, focused light spots depend on the wave length and the size of the antenna (output aperture). Due to the fact that microwave wave lengths are 1000 times infrared light

wave lengths, in order to get the same focal points, antenna diameters must then be 1000 times larger than laser reflector diameters. Besides this, due to the fact that the outer surfaces of the majority of targets at the present time are all manufactured using metal materials, and (illegible) surfaces reflect microwaves very strongly, this then causes the power of microwave weapons to be very greatly reduced.

8-3 Problems Existing with Microwave Weapons

Although, at the present time, microwave generators with very high powers have already been achieved, and, moreover, microwave technology also has a considerable foundation, /171 microwave weapons, however, still have a number of problems. They are that it is relatively easy to shield against microwaves, and microwave weapon focusing capabilities are also not good. In this way, there is then a possibility of making microwave weapons unable to exert their effects in a number of situations. At the present time, people, with regard to research on resisting nuclear explosion electromagnetic pulse effects, have already made very great progress. In similar fashion, people are also capable of hardening military installations, making them capable of resisting the effects of microwaves.

The development scale associated with microwave weapons will not be too large. This is primarily limited by technology development levels at this time. Besides this, there are also limitations from the military position of microwave weapons. Due to the Pentagon and the Reagan administration, right along, taking microwave weapons and arranging them as the third type of directed energy weapons associated with development research, they are also nothing else than the last type of directed energy weapon. Because of this, in this area, appropriation amounts are very small.

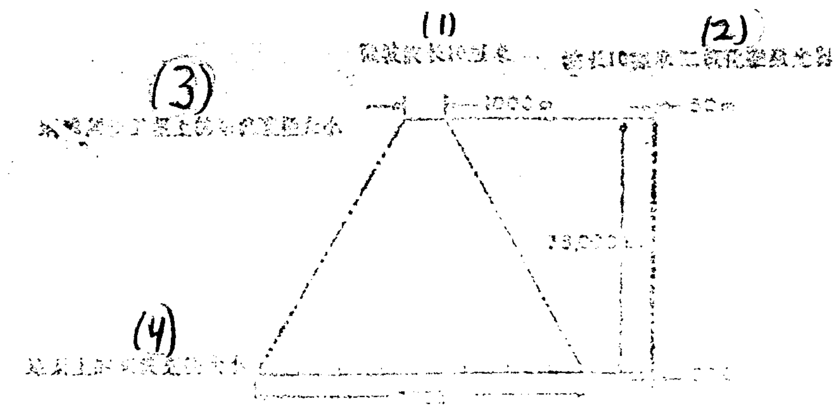

Fig.8-3 As fas as this special point that microwave wave lengths are longer than laser wave lengths is concerned, there are clear differences between "optical components" associated with (illegible) laser and microwave systems. This schematic clearly shows that (illegible) and (illegible) from solar energy satellites (illegible) energy (illegible) optical components associated with (illegible) systems are not the same. In this (illegible), microwave (illegible) lengths are eqivalent to 10(illeg.) centimeters. Laser wave lengths are equivalent to 10 meters (laser light produced by carbon dioxide lasers). The difference between their wave lengths is 10000 fold. It is discovered that there are big differences in the positions of emiting components (as shown in the upper section of the Fig.). There are also (illegible) systems and so on which all have (illegible) differences.

Key: (1) Microwave Wave Length 10 Centimeters (2) 10 (Illegible)meter Wave Length Carbon Dioxide Laser (3) (Illegible) Size (4) Beam Diameter Size on the Ground

If one wants to take microwave weapons and turn them from an idea into a reality, there is still a very long way to go.

Chapter IX OPPOSITION AND ANTIOPPOSITION

People often take the arms race and only see it as building more powerful and bigger bombs, adding even more advanced weapons to weapons stockpiles adequate to destroy the human race a number of times. However, there is a type of subtle, more intellectually demanding arms race which has still not given rise to broad attention from people. This is the "opposition" race. To this end, the U.S. and the U.S.S.R. have both put in large amounts of excellent scientific and technical manpower.

This phrase "opposition" originated with measures adopted in order to oppose enemy offensives. As the name suggests, the purpose of opposition is to cause enemy weapons to malfunction. For example, in the Second World War, the U.K. developed a radio counter, interfering with German bomber radio navigation systems, causing them to lose direction and be unable to strike targets. In another area, in order to smash enemy opposition, it was possible, through developing antiopposition to thwart enemy opposition. This could perhaps be opting for the use of new types of weapons which are not influenced by opposition. This then is antiopposition. In theory, this type of competition can continue right along. This is also nothing else than anti-antiopposition even reaching more and more complicated levels.

Speaking in terms of an engineer, studying opposition is just like a brilliant game of chess. This competition is pressed forward through consummate technology. This type of opposition shows itself as intellectual and technological utilizations. As far as the competition between the U.S. and U.S.S.R. is concerned, in this regard, it plays a role of adding fuel to the flames. Today's antiopposition technology is quite a complicated "black" art. "Black" means not public. Oppositions associated with a number of technologies are electronic oppositions. The

purpose is to cause radars to malfunction, making navigation and launch systems confused or to break up battlefield layouts.

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Despite the fact that this term "opposition" was only recently produced, the idea, however, of making the power of enemy weapons decrease is almost as long standing as the history of military engineering. The armor of medieval knights was the simplest, most effective countermeasure to ward off the commonly used weapons of that time--the sword and lance. A new generation of weapons--for example, small arms and gun ammunition--are capable of penetrating thin layers of metal, causing armor to become obsolete. After this, the penetrating capabilities of shells increased, and tank armor plate followed them getting thicker. This is nothing else than a type of escalation in opposition.

The concept of "opposition" is certainly not that rich in attraction. As a result, it has not yet been able to achieve broad description in science fiction novels. However, there is a point which should receive attention. That is nothing else than that military defense systems should be able to block any enemy warhead or beam penetration. In many circumstances, shields are not always very perfect. A fortress which cannot be penetrated is the most ideal defense system. The pity is that people have no way to build this type of fortress.

9-1 Beam Weapon Opposition

In the opposition arena, beam weapons are certainly not without enemies. One simple reflecting surface is then capable of playing a definite defensive role against attacks associated with high energy laser weapons. Weapons manufacturers foresaw this early on. Waiting for laser weapons to be introduced in real combat, there was certainly no one who did not know this

much and believed that the enemy would take his missiles and paint them black in order to absorb more laser energy.

The latent capabilities of beam weapons in opposition are still far from clear. As seen by outside observers in a number of agencies in the Pentagon, this type of latent potential is very great. As a result, they suggested the establishment of a large model laser for specialized research on opposition roles. However, there are also people who doubt whether or not opposition measures have that much force. It should be pointed out that, even if research brings out very useful opposition measures, it also requires a period of time and only then can they be put into use. In the U.S. Air Force electronic warfare textbook, it says this: "We must not lose opportunities in developing technology. This is a simple and clear question. Because, in the time interval between the instant when the enemy firmly believes we utilize this type of technology and the instant when the enemy adopts opposition measures will give us a very great advantage. In this way, we (illegible) can carry out the next step in the work to maintain our technological superiority." /174

At least theoretically, it is possible to opt for the use of several types of basic opposition measures in order to reduce beam weapon destructive effects. These opposition measures are capable of using several types of methods of exerting effects--for example:

-----Use materials which absorb beams in order to block beams or shield targets.

-----Through reflecting large parts of beam energies in order to prevent beam destructive effects.

-----Make beams spread over relatively large areas reducing damage effects. For example, make missiles rotate (at the

present time, there are already a number of missiles which are capable of autorotation).

-----Use false targets to confuse weapons systems.

-----Once beam weapon attacks are discovered, then adopt evasive measures.

-----Make beam weapons or their ignition systems malfunction. For example, destroy the sensors they use to probe for targets.

-----Replace parts easily destroyed by beam weapons (for example, take satellite solar cell panels and change them into internal electric power sources).

The effectiveness of opposition depends on target and beam weapon properties. For example, if beams are capable of creating destruction in an instant, then making targets rotate or probing for beam emission points will both be of no effect because the first attacking pulse is capable of immediately creating destruction. If beams must loiter on targets for very long periods of time, then this type of opposition measure will play a role. Of course, what is refered to here as a "very long period" only means on the order of seconds.

Another type of opposition measure is to consider opposition systems as aimed at some single part of beam weapons. Some are aimed at beams themselves. Some are used in order to destroy ignition, control, or directing systems. Moreover, some have destructive effects on all of ignition, control, and directing systems. For the sake of ease of description and logical /175 rationality, we begin by talking about opposition aimed at beams.

After that, we turn to initiation and control equipment in general.

9-2 Laser Opposition

The simplest method is nothing else than using a mirror to reflect laser beams. A number of materials with very high natural reflection factors are capable of making it difficult for laser weapons to exert their effects. At room temperature, metal is generally capable of reflecting a large amount of incident infrared light. As a result, targets only absorb small amounts of energy from infrared laser beams. However, sometimes, this small portion of energy is just adequate to heat the metal. Moreover, in general situations, following along with increases in metal temperature, metal absorption rates for laser light also increase.

A number of metals are good reflectors of laser beams. Aluminum is a very often used aviation material. After polishing, it is capable of reflecting 98% of carbon dioxide laser 10 micron laser beams and 95% of 3.5-4 micron hydrogen fluoride chemical laser beams. This difference seems to be very small. However, it means that the latter absorbs approximately twice the energy of the former. Another type of commonly used aviation material--titanium--has a reflection factor of 90% for 10 micron laser beams. In 4 micron wave bands, reflection factors are slightly smaller than 80%. Even though metal surfaces are clean and have been polished, speaking in terms of short wave laser beams, reflection factors still universally go down. As far as aviation materials are concerned, aluminium, in the 0.4 - 0.7 micron range, has a reflectivity factor slightly greater than 90%. Moreover, in this range, titanium reflection is only 50-60%. Due to the fact that material absorption rates are high for short wave lasers, they, therefore, have already given rise to great interest in the U.S. military (see Fig.9-1).

In a certain sense, aluminum's high reflection factors are nothing else than a type of effective opposition measure to

defend against infrared lasers. This point is very important because aluminum, for many years, has been a construction material for the outer shells of aircraft and missiles right along. Later, military research personnel found other materials to replace aluminum continuously, including some materials with lighter weights, better strengths, and shielding roles against electromagnetic waves. Using them to build aircraft or missiles, radars had difficulty in identifying them. However, if these materials are used on the battlefield, they will then present problems because these new materials absorb infrared light better than aluminum. In laser weapon attacks, they are easily damaged.

There are people who consider using a mirror type metal surface to take laser beams and reflect them back to the laser thereby destroying its sensors or creating other damage. However, this type of idea is not practical. Due to the fact that plane mirrors or smooth curved surfaces must be positioned at special angles and, in conjunction with that, carry out accurate aiming, and, only then is it possible to make a large portion of the energy return to the laser, even if things are this way, beams on their return paths will still experience /177 diffusion. As a result, the energy arriving at the laser is not worth mentioning. There is a type of "back reflection mirror" which is capable of returning laser light along its path of incidence. However, its surface shape is difficult to employ on real aircraft.

Clean and smooth surfaces are capable of reducing damaging effects during laser irradiation. However, in actual applications, aircraft are not capable of achieving complete flatness and smoothness. Very small surface irregularities, pits, scratches, as well as metal plate connections are all capable of becoming breakthrough points for laser weapon attacks.

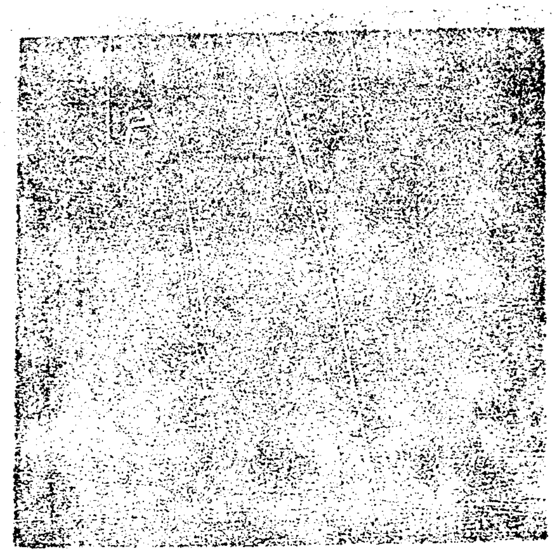

Fig.9-1 This type of geostationary orbit laser satellite having opposition systems is different from other satellites. The countermeasures they possess make them capable of withstanding laser weapon attacks. This satellite was launched by the U.S. NASA in 1976. 426 (illegible) return reflection device (illegible) reflector mirrors of 60 centimeter diameters cover the satellite surface. These reflector mirrors take fired laser light and reflect it back to its original launch location. This type of satellite can be used as a low power laser rangefinder, accurately measuring the position and height of surface objects. Surface reflector mirrors are a help in measurement operations of the rangefinder. The protective layer on the entire satellite is unusually expensive. The price of each piece of mirror in 1975 was 600 U.S. dollars. The total price approached 250 thousand U.S. dollars. However, these mirrors were not capable of withstanding the effects of high power lasers. They were also not able to reflect and refocus them on a certain small spot associated with the laser launch location.

In these irregular locations, metal contact point binding forces are weak. Light beam powers at these locations are relatively concentrated. As a result, it is easy to give rise to damage. Pollutants on the surface are also very dangerous because they will increase the absorption rate for laser energy.

One type of method for resolving this problem is nothing else than polishing surfaces. This is also nothing but making ground crews polish the outer surfaces of aircraft before they are put into combat. Another type of method is to opt for the

use of very strong reflection layers. Research personnel have already discovered that special covering layers are capable of making metal reflection factors for infrared light rise to 99.1%. Theoretically calculated reflection factors are capable of reaching 99.8%. However, this most certainly does not mean that this type of surface is not easily destroyed in a laser attack because this type of surface is capable of being fouled with contaminants. Even if the surface is clean, it will still absorb small amounts of optical energy. When laser powers are very great, in the end, they will heat surfaces causing temperatures to rise. Optical energy absorption rates will also follow along and rise.

There are people who put forward ideas similar to those above. However, they utilize very complicated opposition measures. Among these, one type of method is to use a number of reflection balloons to wrap up nuclear warheads. Another type emphasizes using spinning missiles or warheads, taking laser energy and diffusing it onto a relatively large area. The shortcomings in the two types of methods are that they both require designing anew these "potential targets". At the same time, they also complicate the guidance associated with the protected ballistic missile or nuclear warhead.

The Pentagon is in the midst of looking for other methods to block laser beams from arriving at target surfaces. There is a type of natural phenomenon worthy of attention. That is nothing else than, when strong laser beams heat targets, target surfaces will give rise to thermal vaporization of materials. To the same degree, this will automatically block beams arriving at target surfaces. Material vapor floats above the surface. This vapor is capable of absorbing even more energy. In the end, it will ionize into plasma. These plasma bodies will also be able to absorb even more energy. When laser powers are very strong--for example, when carbon dioxide laser beam power densities reach

107 watts/cm^2 --these plasma bodies will form a type of wave. It is capable of advancing through air in the direction of the laser beam. This type of "laser supported absorption wave" spreads unceasingly toward the beam until a place where it does not have adequate laser beam power to sustain the propogation and stops. When engineers use lasers to carry out metal working, this type of effect was seen. It will produce very clear noise and flash and is capable of being repeated several times within a period of a thousandth of a second. As far as this type of phenomenon is concerned, there is a clear laser power threshold value associated with blocking laser beam irradiation to the surface. Under this threshold value, laser powers transmitted to target surfaces follow along with increases in laser beam power and abruptly decrease (see Fig.9-2).

This type of plasma effect is capable of becoming an opposition measure associated with thermal plasma shielding targets. Military engineers are always looking for special coatings--called stripping coatings. Under laser irradiation, this type of coating will vaporize and form plasma shields. The specific situation is very complicated because plasma body formation is determined by mutual effects of laser beams and the surrounding atmosphere. Moreover, there are also influences from gas pressures and target movement speeds.

Plasma is certainly not always a type of countermeasure. In certain situations, plasma is capable of raising energies transmitted from laser beams to targets or producing other damage on targets. Ultraviolet lasers are even capable, after the formation of plasma, of heating targets according to the pattern. High temperature plasma is capable of producing approximately 10 atmospheres of pressure. Pressures this high can then (illegible) cause surfaces to sustain destruction before target surfaces melt in laser beams, thus reducing the laser power required to produce damage.

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Another method of blocking laser beams is nothing else than spreading a type of smoke material in the atmosphere. On the battlefield, the air is often filled with smoke. Infrared measuring equipment which is often used militarily makes soldiers look somewhat farther away in the air filled with smoke and dust. However, military personnel believe that the concept of visible light smoke blockages requires the addition of correction and amplification. Destruction of and interference with infrared equipment vision is also one effect of smoke blockages. Atomized oil is just one example. It is a product of incomplete combustion of diesel engines.

Weather is also capable of acting as an opposition measure. The Pentagon is very interested in European fog, (illegible), rain, snow, as well as cloudy weather because these will all /180 influence the normal operation of weapons systems based on optics and infrared sensors. Small water droplets in fog are capable of making vision obscured because they will cause light to give rise to intense scattering. However, following along with increases in wave length, scattering influences are reduced. Snow can bring with it more complicated problems. Certain observers express objections with regard to the Pentagon's excessive trust in optical or infrared systems. In conjunction with this, they warn that the uses of weapons which can be employed only when the weather is good are limited. With regard to defense weapons, this is particularly so because the enemy can select the weather conditions suited to attack.

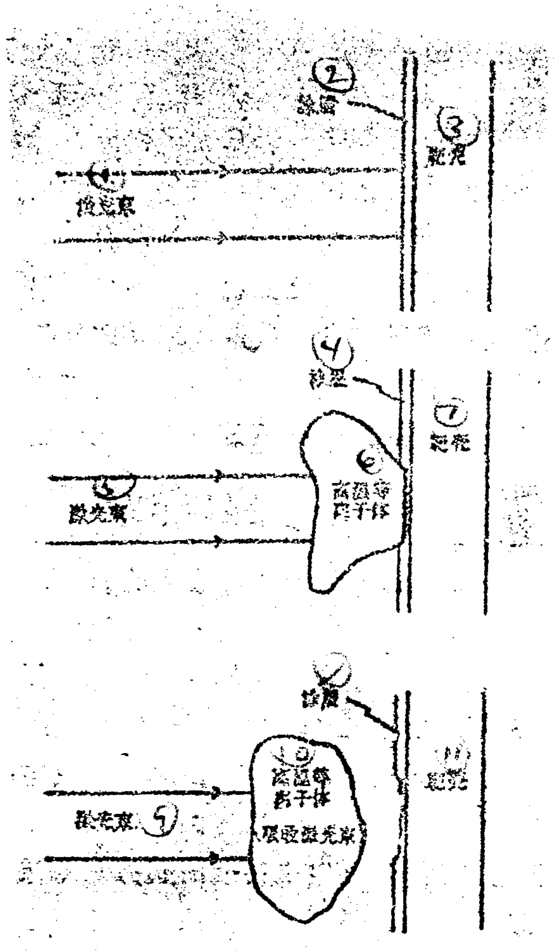

Fig.9-2 One type of (illegible) antilaser measure is (illegible) to paint a type of special material on targets. When they receive laser irradiation, this type of material vaporizes to produce high temperature plasma. This type of plasma absorbs incoming laser light thereby achieving the purpose of protecting targets. What is shown in the Fig. is this type of process from top to bottom and the priority order associated with protection functions.

Key: (1) Laser Beam (2) Coating (3) Target Shell (4) Coating (5) Laser Beam (6) High Temperature Plasma (7) Target Shell (8) Coating (9) Laser Beam (10) High Temperature Plasma (Illegible) Laser (11) Target Shell

Strong light beams associated with high energy lasers can "burn through" fog, smoke, as well as other disadvantageous air conditions which influence the line of sight of soldiers and sensors. The Pentagon has already carried out experimental research on various types of possibilities for producing this kind of effect. This includes using laser beam scanning methods to dispel fog on airfields. Up to the present time, numerous types of "tunneling" methods have already been tested. The only question which is not clear is: How big an effect can this type of technology produce in advancing weapons system character-isitics? In fog, the amount of heat required to punch a hole is capable of producing heat diffusion effects or leading to the production of turbulence which is very difficult to use optical systems to correct. When targets move rapidly, in each string of laser pulses, there must be one pulse used in order to punch a new aperture so as to facilitate forming a path of continuous air area between lasers and targets. If, in the boring process, there are produced materials which absorb light-- such as smoke residue, beam ion materials, and so on--this will then give rise to some new problems. If ignition and control systems are not able to "see through" air in order to identify targets, then the work of cleaning up laser beam paths will then become absolutely meaningless.

One type of very interesting natural opposition measure is lightning. Electricity released in the atmosphere has a path along low electrical resistance. That is also nothing else than a propogation tendency toward the path with the most numerous ions (due to free electrons and charged protons that have lost electrons, it is, as a result, possible to conduct electricity).

If high energy laser pulses are capable of producing adequately numerous ions, it is possible to imagine that lightning will then follow the ion path and hit the light source, that is, laser weapons. This problem is very severe. However, up to the

present time, in laser weapon tests, it has not been encountered. Despite this, in the laboratory, laser beams are still often used in order to set up a "path" for electric discharge and electron beam propogation. /181

If among oppositions associated with defense against laser weapon attacks, there is included a counter strike against the laser weapons in question, then one knows that the installation point of the lasers in the midst of being utilized is unusually advantageous. Currently available probing instruments are capable of discriminating whether or not a target has been irradiated by laser beams. Moreover, it is possible to fix from where laser beams were fired. If laser beams fire once in microsecond periods, and it is then possible to create lethal damage, the use of this type of counter attack form is very limited. If this type of damage requires sustainments on the order of seconds, then this type of capability is very beneficial. It is possible to imagine that, if the direction of a laser has been determined, then another laser is capable of carrying out a counter strike against it.

During laser offensives, opposition measures protecting sensors and opposition measures protecting other potential targets are somewhat different. This is because protecting sensors is aimed at low energy lasers. Low energy lasers do not need to make sensors produce heat or mechanical damage in order to "knock them out" or make them lose function. When protecting infrared or optical sensors, one must also consider a number of other complicated factors. If one takes these sensors and hides them in a place where light cannot enter, then there is no way for them to operate. This requires having a type of opposition measure capable of reflecting the attacking light beams and still allowing light beams which must be sensed during sensor operation to enter. Special types of optical filters are capable of doing this. They are capable of reflecting out attacking light beams

within a very narrow wave length range and letting light in the other portions of the optical spectrum penetrate. This then holds the possibility, during attacks by 10 micron carbon dioxide lasers, of protecting infrared sensors. At the same time, it is possible to carry out observations of light in other wave lengths. This type of "exclusion" filter is certainly not perfect in every way. However, this type of filter is capable, in the final analysis, of supplying a type of simple protective means for sensors. Because, when manufacturing sensors, it is necessary to know the wave length of the attacking lasers, as a result, reflection wave lengths of specially designated filters are also capable of being fixed.

Another type of method for protecting sensors is covering them with layers of material that turns dark under strong light. Optical glass containing chromium and used in solar mirrors is an example familiar to every one. In military terms, "flash protection devices" have already been developed. They are capable of turning dark in periods of microseconds to /182 milliseconds. The purpose of utilizing this type of device lays in protecting the eyes of bomber pilots and other soldiers in order to avoid being blinded by the flash of distant nuclear explosions. In certain situations, this type of method is valuable. However, its uses are limited. In the case of bomber pilots, it is only possible to guarantee that they are not blinded by light produced by nuclear explosions (this type of effect is similar to the reaction of eyes to brilliant flash bulbs). However, it is not possible to guarantee that pilots will not be injured by the effects of nuclear explosion radiation. During laser light irradiation, glass or other material turning dark will block sensor "vision". They will only be able to restore function after the laser light disappears. This is undesirable. Materials absorbing light can also be

easily damaged by high power lasers because they rely on absorbing light beams and not reflecting light beams in order to protect sensors.

9-3 Particle Beam Opposition

As far as opposition measures with regard to particle beam weapons are concerned, extensive research has still not been carried out. They are not so easy to understand as countering laser weapons. The primary reason is that each particle in beams has very large shock forces. The energies of each of them individually are several million times higher than the energies of photons. This energy is adequate to make particles bore through metals and deep portions of a number of target materials (see Fig.9-3 and 9-4). It is only necessary that these targets be able--in air or in space--to penetrate very large distances, and they will then be capable of instantaneously destroying targets. Moreover, antilaser coatings on target surfaces have almost no way to block them. Besides this, speaking in terms of charged particle beams, clouds and rain are certainly not more severe obstacles than air.

There are a number of methods capable of offering choices which can block beams and make beams change direction. Experiments verify that a very thin layer of air is then capable of interupting the propogation of neutral particle beams in space. One method of taking this layer of air and sending it into outer space is nothing else than exploding in the upper atmosphere a small nuclear warhead, forcing part of the air to enter between space particle beam weapons and targets. People putting forward this idea believe that, when neutral particles penetrate the equivalent of a 1 micron thickness of air at normal temperature and pressure, they will then lose electrons and /183
become a charged particle beam and unable to continue high density propogation in outer space. However, exploding nuclear

warheads in space will lead to other problems, including (illegible) some attendant threats to the protected targets. As a result, it is still not clear whether this type of method is feasible or not. What is worth bringing up is that, at 100 kilometer altitudes, there is still some air. It is also capable of producing mutual effects with particle beams. Charged particle beams are very easily deflected by strong magnetic fields. Nuclear explosions are capable of producing strong instantaneous magnetic fields. However, what should be considered is that nuclear explosions cannot be just carried out at one's convenience.

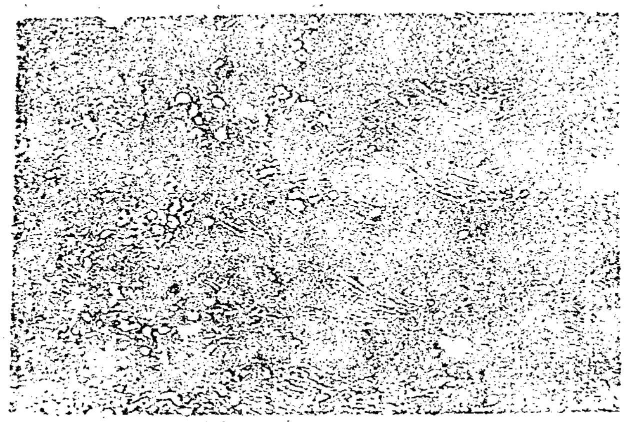

Fig.9-3 This is a photograph of damage sustained by particle beam irradiation of a 1 micron thick aluminum plate. It says (illegible) with regard to the adopting of countermeasures to defend against particle beam weapons. The bottom part of (illegible) plate has had two thirds of its thickness penetrated by particle beams. At this time, the metal has been melted, and violent shock waves cut out a big piece of the surface of the aluminum plate.

A number of observers believe that attempts to defend against strong particle beams being able to punch holes through metal plates is a waste of effort. However, with regard to shielding and hardening of (illegible) targets in order to resist and diffuse particle beams, it is feasible. The Pentagon is in the midst of striving to harden its hardware in order to withstand the "electromagnetic pulse" effects produced by nuclear explosions. This type of hardening method is also capable of increasing resistance capablities to diffused particle beams. /184

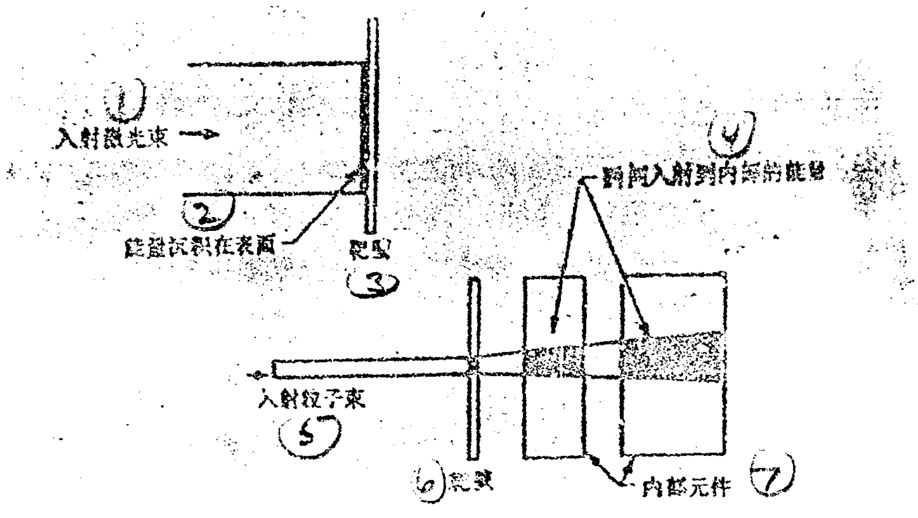

Fig.9-4 As compared to visible light or infrared laser beams, particle beam depths of target penetration are deeper. Moreover, particle beams are also capable of penetrating target walls and target shells to destroy components inside. As a result, defense against particle beam weapons has become unusually difficult. However, with regard to laser beams, they must first burn a hole in target walls, and only then are they capable of destroying interior components. (key on following page)

Key: (1) Incident Laser Beam (2) Energy Accumulation on Surface (3) Target Wall (4) Energy Fired Inside (Illegible) (5) Incident Particle Beam (6) Target Wall (7) Interior Components

9-4 X Ray Laser Opposition

X ray laser weapons require special opposition measures. X ray photon energies are 1000 times those of visible light. They are one one thousandth the energies of neutral particles used to make particle beam weapons. Different from electrically charged particles, X rays are not capable of being deflected by magnetic fields. After X rays arrive at targets, their penetration energies are between long wave lasers and particle beams. Just as was brought up before, normal materials do not actually reflect X rays. As a result, X rays are capable of penetrating targets very, very deeply. From a few millimeters to a few hundred, or a few thousand millimeters, this depends on wave length and material. Shielding against dispersed X rays is somewhat easier than shielding against dispersed particle beams because X ray penetrations are not so deep as particle beams. However, shielding against high strength X rays is not practical because they will produce physical and shock wave damage on all attacked targets.

Here, it is important to discuss a bit some questions associated with when X rays penetrate air. Highly classified Livermore lasers are capable of producing X rays with 14 μm wave lengths. This type of X ray, at sea level air densities, has a penetration distance of only 1 millimeter until one half the radiation has been absorbed. Following along with reductions in wave length, absorption is also reduced. In the short wave band associated with the X ray zone, even as far as when wave lengths are 1 μm , the absorption question is still a very severe problem.

Precisely hitting the core problem is the perplexing thing about opting for the use of X ray laser weapons. This is primarily due to people still lacking adequate knowledge with regard to X ray laser technology. If it is required at a certain instant to initiate a laser weapon, in that case, it is then necessary to set off a nuclear bomb to supply power for all the X ray laser weapons in the combat station. This is nothing else than equal to destroying the entire combat station. If an X ray laser combat station is alone in space, then the entire combat station may possibly be used to destroy only one (illegible) target. If, at a certain instant, there is only one missile coming to attack and it is let go, the consequences would be disastrous. Intercept it, and the combat station used to block large numbers of missiles will perish together with it. In order to avoid this kind of problem, it is necessary for a second missile defense system to act as an auxiliary. In this way, it is then possible, at the same instant, to destroy a number of missiles. Looking at this, earnest study of X ray laser knowledge is very necessary.

9-5 Microwave Opposition

As far as research work carried out in the area of microwave directed energy weapon opposition is concerned, it is extremely inadequate as compared to research work carried out on microwave weapons themselves. Despite the fact that huge antennas are targets most easily inviting attack--as far as the effects of high power microwaves are concerned, however--among weapons systems, they still have their place. There is a most simple measure for handling low power microwaves. This is nothing else than shielding. Microwave shielding is much easier than X ray and particle beam shielding. Due to large scale utilization of microwave equipment in the military, microwave shielding

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technology has achieved quite large developments, even to the point of also seeing them in consumer products--for example, microwave ovens.

The Pentagon hopes to be able to utilize shielding systems in order to cope with microwave weapons. Moreover, it recognizes that the basic effects of microwave weapons will depend on how great the capability to penetrate shielding is. However, it should be seen that shielding is certainly not the only defensive measure. Electrical signals can be changed into optical signals.

When they are transmitted through optically conducting fibers, they will not be interfered with by microwaves. There is a possibility of using a number of integrated optical devices to replace certain electrical devices. However, at the present time, they are still in the laboratory stage.

9-6 Fire Control Opposition

As far as previous discussions are concerned, fire control opposition associated with beam weapons is of key importance. In a situation where the U.S. and the U.S.S.R have both put great stress on the development of electronic warfare, beam weapon firing systems then become a prime target for opposition.

Electronic warfare originates from the First World War but only really came to the fore in the Battle of Britain in the Second World War. At that time, Britain and Germany both were striving to improve the accuracy of air raids. First of all, targets were concentrated on navigation systems. However, they very quickly turned to radar systems. Britain led Germany. They utilized radar systems first.

Today, electronic warfare is an unusually complicated, unfathomably deep field. In combat, direction finding, navigation, and radar installations, communications systems, aiming systems, as well as other equipment are all important targets. In the areas of interference blocking of radar and communications as well as preventing interference, large amounts of research work have already been carried out or are in the process of being carried out. It can be imagined that large amounts of work are top secret. They are also very abstruse. This book does not discuss them in detail. Here, it is only our idea to stress somewhat that electronic firing systems used among beam weapons are prime targets of electronic opposition. As a result, it is then also necessary to adopt electronic anti- opposition defenses.

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Traditional microwave radar can be used in certain beam weapons. However, high precision requirements need help from short wave radars. They operate in the micron, infrared, and even possibly in the visible light areas. They have relatively good resolution. However, this type of radar system can easily be interfered with by bad weather. Directed energy beam powers are very large, capable of forming channels. Compared to them, the influences undergone by fire control radars in association with bad weather are relatively large. On the battlefield, beam weapon fire control may depend on microwave radars because their ability to penetrate thick foggy atmosphere is greater than short wave systems.

Radars and sensors themselves are most easy to destroy with beam weapons and conventional weapons. Microwave radars will become the targets of enemy radar seeking missiles. This problem should receive serious attention. Beams associated with laser radar and millimeter wave radar are very narrow. Enemy missiles have great difficulty aiming. However, the systems in question still easily encounter other forms of destruction. Optical sensors and infrared sensors will show the appearance of overload effects due to excessive amounts of light they lead to. When lasers of appropriate power are just adequate to destroy sensors- -in particular, sensors using telescope methods of light gathering--this is even more the case. In some situations, it is only necessary to make sensors temporarily lose their effectiveness. This has the same kind of principle behind it as bright vehicle lights making people lose their night vision. (illegible) High energy (illegible) light is capable of taking adequate power and throwing it onto sensors. With regard to the electronic circuitry associated with other parts of sensor and

transmission systems, permanent damage is created.

As far as sensors and auxiliary electronic circuits are concerned, it is also easy to undergo damage associated with other attack weapons. High power microwaves, strong magnetic fields generated by interference sources, electromagnetic pulses produced by nuclear explosions, and so on, are all capable of producing severe destructive effects on electronic circuitry. Normally, electromagnetic interference originates in the operational processes of electromagnetic equipment--for example, radio transmitters, automotive spark plugs, electric pencil sharpeners, as well as microwave communication systems which are spreading every day. There are people who, when they sit in front of a computer and make use of an electric pencil sharpener, are surprised to discover loss of data on the screen. This is just one case in point. Due to the fact that semiconductors can only operate in low voltage systems, they are easy to interfere with and destroy. Although certain military systems have more or less preliminary shielding to protect against these effects, they are, however, not adequate to shield specialized aiming sensors or electromagnetic radiation associated with electronic systems.

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Until 1981, before Leiluofu (phonetic) (science news magazine) and Bailaode (phonetic) (science magazine) discovered electromagnetic pulse effects, this effect was still a secret discussed in the Pentagon. The basic problem it involved was very strong electromagnetic fields produced by nuclear explosions. This type of electromagnetic field radiates outward from the explosion site, producing very great destructive effects. In electronic circuitry far distant from the site, it will give rise to very great instantaneous currents. With regard to nuclear explosions

in space, this problem is even more severe. They produce very strong electromagnetic interference within a very large area on earth. In spaceships, they produce shock waves with destructive effects.

As far as temporary interruptions of electronic circuits are concerned, they will erase information stored in computers. In conjunction with this, there is a possibility of creating permanent damage to electronic circuits. Based on the point of view of the Pentagon, the toughest (illegible) problem is there being no way to measure the magnitude of this type of effect. Theoretically speaking, preventing electromagnetic pulse effects is possible. However, in reality, there is almost no equipment capable of opposing this type of interference. The U.S. nuclear physicist Teller has humorously said: "In situations where there is universal option for the use of electronic computers, due to the effect of strong electromagnetic pulses, I think, discovering instruments capable of continuing operation will be very much easier than finding instruments that have stopped operating."

In the case of a number of observers--particularly Bailaote (phonetic)--it is believed that electromagnetic pulse effects are the Kryptonite of space beam weapons. To use their words: "One nuclear explosion in outer space will immediately, in several hundred satellite combat stations, set up approximately 106 volts/meter of electromagnetic field, rapidly destroying solid state circuits and ending their combat capabilities." However, beam weapon observers doubt that electromagnetic pulses will have fatal effects. They point out that the reason beam weapon researchers take great pains to stress this point lies in the Pentagon's primary concern being to demonstrate technological feasibility--not to design weapons systems. In conjunction

with this, it is believed that beam weapon researchers may possibly start with electromagnetic pulse effects in order to expand development of other work. Currently, what the military is primarily interested in is the lack of presently existing equipment defended against electromagnetic pulses because it will be even more expensive to add a certain function to a currently existing piece of equipment than to build new equipment having the function in question. However, some of the most recent (illegible) reports point out that electromagnetic pulse effects are not as frightening as originally thought.

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One most conventional opposition measure associated with beam weapons is nothing else than confusing initiation systems to make them attack false targets or to use a number of targets which they cannot attack in order to make beam weapon responsibilities heavier. Early applications of this way of thinking were in the Second World War--for example, British aircraft, in order to confuse German radar, threw out pieces of aluminum. A somewhat more complicated method is nothing else than sending out large numbers of false targets and small numbers of real targets. If space beam weapons are not capable of discriminating attacking real warheads and false targets, then it is necessary to rapidly destroy all the possible targets. This is a much more onerous operation than simply knocking out warheads carrying bombs. If false targets make defensive weapons system responsibilities excessively heavy, then there will be some real warheads penetrate.

9-7 Ease of Weapon Damage

No matter whether it is on the battlefield or

in space, beam weapons are certainly not all infinitely powerful. In the same way as other weapons systems, they can be destroyed by enemies possessing advanced weapons systems and rich experience. On the battlefield, beam weapons are not only easily attacked and destroyed by blitzkrieg in opposition. Moreover, they also easily perish in all out attacks. Space beam weapons are most easily destroyed in launch and assembly phases. The reason is that, speaking in terms of the enemy, destroying them before the beam weapons create a threat to him, the risk run will be much smaller. There are also other methods capable of destroying space combat stations. If one takes steel balls or metal mesh and throw them in the same motion path as beam weapons--however, with an opposite direction of movement--collisions between the two in this way are capable of destroying them. Besides that, it is also possible to install in orbit command detonated explosives.

9-8 Anti-Opposition

If beam weapons are installed in outer space, then the escalation from opposition to anti-opposition is really undoubted. However, in relation to this type of possibility, very few people talk about it. One basic reason at the moment is nothing else than that the most aggressive proponents are precisely opponents of the development of beam weapons. The Pentagon encourages a certain amount of anti-opposition work. However, most of the details are secret. As a result, it is only possible to introduce some simple and plain examples.

As far as one type of possibility associated with anti-opposition is concerned, it is nothing else than making use of special laser beam penetration beam blocking materials

(for example, plated layers capable of volatilization or plated layers with high reflectivities, and so on). One series of very short strong pulse beams is capable of making covering layers melt. It is also capable of penetrating to the interior. If the time interval between two pulses is relatively long, then it is possible to make light absorbing plasma bodies scatter and disappear, or, using pulses with relatively short intervals (the best are free electron laser), then it is possible to make surfaces produce a number of damage points. In this way, attacks on targets by pulses with relatively long intervals or continuous beams then seem easy.

Another type of possibility is to use variable wave length lasers. Pentagon research personnel believe that light beams associated with this type of laser, designed for low power targets, are very difficult to detect because currently existing detection methods require depending on laser wave length. Using this type of method, it is possible to prevent targets taking some specially designated wave lengths and filtering them out or reflecting them away. Adjusting output wave lengths, it is possible to make their wave lengths and surface material absorption match up. Free electron lasers are the lasers having the best hope of satisfying these conditions.

Very clearly, following along with the development of beam weapons, competition between opposition measures will become even more intense. However, no matter how high the price, it is still difficult to add confirmation to the effectiveness of antilaser weapons theories. People have great difficulty making those military commanders who understand enemy weapons believe that enemy weapon aluminum shells have no protective capability. Obviously, the actual cost of opposition is the primary core of debate. However,

before formal rulings, there are still a number of key questions which must be answered. /191

Chapter X HIGH TECH WEAPONS AND MODERN WARFARE

Approximately 18 years ago, the deceased American Jiemusi Bulishen (phonetic), in a science fiction work, described a story. Mankind carries out a battle with units of monsters from hell. Because the battle is extremely arduous, mankind employs advanced weapons, large robot forces, and automatic weapon equipment. Finally, the satanic evil spirits and their forces are driven off the earth. To act as a reward for protecting human civilization, the robot army that had made contributions in the war was sent to heaven, and the generals who directed this war, to the bafflement of people, were, however, left behind.

Bulishen's (phonetic) story of mechanized war is far from having the reality and credibility of H.G. Well's "War of the Worlds" written 70 years earlier. However, Bulishen (phonetic) still gives people this kind of enlightenment: war is not merely weapons and technology, it has a much deeper meaning than this.

Seen from the point of view of weapons, science fiction novels relating to robot heros are not able to satisfy people. At the present time, there are, already, no people who will believe that one should take two legged robots such as C3-PO in the film "Star Wars" or Luobi (phonetic) in "Dangerous Planet" and use them on the battlefield to replace soldiers. However, robots, in the minds of Pentagon planners, still occupy a very important position. Military planners often talk about relevant automatic initiation

systems--systems capable of aiming at enemy targets, and, in conjunction with that, automatically firing. They also talk about "launching and automatic tracking" weapons. This type of weapon only requires soldiers to find the target, and, in conjunction with that, pull the trigger. The weapons system will then do the rest: tracking the target and, in conjunction, destroying it. This type of weapon is equipped with ingenious IFF (identification-friend-or-foe) systems. They are capable of automatically distinguishing targets. Military engineers also give consideration to using /192 "intelligent" computers to control weapons systems on the battlefield. Moreover, they speculate on the prospeect of war in space: battlefield satellites equipped with automatic control systems controlling fleets of ICBM's carrying guidance systems. A new generation of mechanical weapons on the verge of coming out does not include any robots. There are some systems, in the plans for which, option is made for the use of what could be called "robots". These are nothing more than mechanical equipment like automatic systems used on production lines.

War is in the process of turning from a battlefield of people to a battlefield of technological equipment. U.S. strategists are in the midst of searching for a technological superiority in order to surpass the Soviet Union's superiority in numbers. Military officials are striving to spur the development of even more modernized technology. This type of method of doing things will bring with it severe consequences--stimulating the arms race and leading to increases in nuclear equipment. Changes in military thinking are broad--strength or weakness in military power is determined by the number of nuclear warheads; soldiers are all equipped with high technology weapons of high destructiveness, and they are not rifles any more; aircraft and modernized missiles play a decisive role

on the battlefield; electronic, optical, and infrared systems guide missiles and other weapons in aiming at targets. Progress in the area of electronic systems will finally make it unnecessary for command personnel to be on the front line to be capable of directing combat. The Reagan administration is now in the midst of eagerly looking for new technology capable of defending against nuclear attacks.

Beam weapons are capable of adapting very well to this type of requirement in the evolution of weapon development. Their primary effect is to make enemy weapons malfunction or be destroyed--not to attack soldiers themselves. At the same time, beam weapon technology is highly modernized. Below, we make a simple description of the current status of this type of high technology weapon.

10-1 Strategic and Tactical Weapons

In the traditional way of speaking, in the military, weapons were habitually categorized as tactical and strategic. At the present time, these two fields are both in the process of opting for the use of new technology in accordance with their own requirements. Directed energy technology is capable of exerting an effect in both these two fields.

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Strategic weapons, roughly speaking, are used in order to destroy weapons capable of supporting a war (or launching a war). In actuality, even more of the effect of strategic weapons is deterrence, that is, using attacks which create large scale destruction in order to threaten the enemy, preventing his preemptive activities at the outset. What "strategic target" refers to is "military installations,

broadcasting networks, building complexes, weapons manufacturing industries, as well as certain special targets." In reality, the phrase "strategic target" has already been expanded to include the opponent's strategic weapons--for example, spy satellites, and so on.

Tactical weapons are used in order to attack weapon targets on the battlefield. Normally, their manufacturing costs are relatively low. The targets are primarily on land, on the sea, and in the air. Tanks and rifles are tactical weapons, but long range bombers and ICBM's are strategic weapons. There are some tactical missiles also equipped with small nuclear warheads. To believe that all nuclear weapons are strategic weapons is incorrect.

Beam weapons can be used both on strategic targets as well as on tactical targets. One type of beam weapon is only capable of use on strategic targets or tactical targets--not both. The long range lasers and particle beam weapons which President Reagan proposed to use in order to defend against strategic bombers and missiles belong to strategic weapons. Because targets they attack are strategic weapons, antisatellite weapons are also strategic weapons due to most satellites possessing strategic intent--for example, observing the strategic strength of the other side or supplying long distance communications. Short range beam weapons, by contrast, are used on battlefields on land, sea, and in the air. As a result, they are called tactical weapons.

10-2 Strategic Military Weapons

The main components in strategic arsenals are nuclear bombs. They are capable, by bomber or missile, of being launched over long distances to enemy territory. Traditional defense strategists use three (illegible) analogies in order to talk about the strategic trinity, that is, land launched ICBM's, submarine launched ballistic missiles, and long range bombers. Each type within the U.S. strategic defense trinity is capable of making a nuclear
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attack on the Soviet Union. Of course, each/194 type also has its various advantages and disadvantages. Land based ballistic missile attacks are accurate. However, they will circle half the globe in an approximately half an hour period. As a result, the opposition's spy satellites can very easily identify their trajectories. Destroying them is, of course, relatively easy. This becomes the focus of the debate around the MX missile. Submarine launched missiles are not too accurate. To a very large extent, this is due to errors when measuring target position. However, submarine launches cannot be discovered easily. As a result, they are very difficult to intercept. As far as bombers--the oldest type in the strategic trinity--are concerned, they are much slower than missiles and can very easily undergo interception by the opposition's air defense capabilities. However, bombers are capable of taking off when they receive attack warning. As a result, they are capable of raising their survivability. They are piloted by people and possess flexible maneuverability, appropriate to carrying conventional bombs and air launched cruise missiles. Some observers believe that they should act as another leg of the strategic defense because their nap of the earth flight tracks are very different than high

altitude ballistic missile trails resembling arcs. Based on the reasons discussed above, one should take the trinity and change it into a quaternary. However, this type of suggestion has still not gotten broad response. Despite the fact that the Soviet Union's real power in the area of land based ballistic missiles is somewhat stronger, the composition of their military strength, however, is roughly similar to that discussed above.

The role played by satellites in strategic defense is different from the weapons discussed above. Without doubt, however, they are of key importance. Both the U.S. and the Soviet Union have launched large numbers of spy satellites, used in order to observe the activities of the opposition. In conjunction with this, they supervise the fulfillment of the arms control treaty. As far as low orbit operation of satellites is concerned, the resolution capabilities of photographic systems can reach 15-30 centimeters. This is adequate to clearly distinguish targets on the ground. It is also useful in order to monitor electronic spy satellite microwave transmission signals. There are also a number of satellites constantly observing signs of nuclear attack. For example, through detecting the hot gases associated with exhaust, it is possible to know whether or not a group of ballistic missiles have been launched. Satellites are also capable of indicating the position of the other side's surface ships. The U.S. and the U.S.S.R both make extensive use of communication satellites to serve the various individual military bases all over the world. There are also a number of other military satellites used in providing navigation, environmental monitoring, drawing maps, as well as carrying out geodesic measurements needed to guide

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missiles. Studying the status of satellite launches each year, it is possible to see that the largest employer is

military authorities. This type of situation has already drawn the attention of observers outside the U.S. and the U.S.S.R.

President Reagan developed proposals for technologies to defend against nuclear attack. However, these are the newest types among a number of suggestions to set up systems to attack strategic missiles, bombers, and satellites. In this area, the U.S. has already spent large amounts of money and put down a very large stake. However, very many people believe that it is impractical and basically not worth the spending of all that money. In spring of 1983, before the Reagan "Star Wars" speech was given, both the U.S. and the U.S.S.R were in the midst of negotiating the arms control treaty. After the Reagan speech was given, the Soviet Union then rapidly made a reaction. However, both sides still continued to carry out consultations on arms control questions. This type of negotiation and consultation has been carried out right along for the last many years. Progress is slow, and often side issues come up unexpectedly. Although this is the case, the negotiations have still produced a number of results. The SALT-I treaty was signed. Somewhat later supplementary treaties were also added. The treaties stipulated that both side's antiballistic missile systems not be more than one. In conjunction with that, they forbade using antisatellite weapons against the other side's satellites. In reality, these limitations certainly did not have the effects they should have. On the contrary, they still brought on even greater development of antimissile systems.

Beam weapons are one type among weapons systems recommended as being capable of satisfying the Reagan administration requirements. In fiscal 1983, the actual expenditures on ballistic missile defense systems did not

reach President Reagan's suggested target of 1 billion U.S. dollars. Moreover, most was used on industrial processes and technology problems and not on beam weapons themselves. Among beam weapons, the most recent targets are land based, air or outer space antisatellite laser systems. The development of high energy lasers and other directed energy weapons proposed by President Reagan for defending against nuclear attacks must travel a very long road, and only then will it be possible to make feasibility evaluations on them.

10-3 Types of Nuclear War

Nuclear weapons play decisive roles in modern military strategy. The most important lies in being able to set up a type of balance of power through them. Perhaps calling this balance of power the nuclear balance of terror would be somewhat more fitting. Its foundation is the "mutually assured destruction" (called simply MAD) strategy. The content of the "mutually assured destruction" strategy is that even if the other side launches a preemptive nuclear attack, one's own side will still be able to preserve adequate nuclear weapons in order to completely destroy the other side.

The new starting point of President Reagan's idea is to take defensive strategy and turn it from passive mutual destruction into active defense against nuclear attacks. A number of observers point out that strategic defense plans sound very new. In reality, they have already existed for many years. Inside the Pentagon and outside it, they have staunch defenders. This strategy requires that both sides exert every effort to avoid using "warning attacks" capable of leading to warning failures, in conjunction with this,

leading to nuclear attacks which cannot be recalled. This also explains why both sides are in the process of building huge nuclear weapons arsenals capable of destroying both sides several times.

It is also possible to have different views of nuclear war. One type is a pure "tactical" war. It is limited to a certain battlefield. In view of the military power of NATO and the Warsaw Pact being close to each other in Europe, as a result a number of Europeans worry that their countries will be turned into a nuclear battlefield. This type of anxiety is not without reason (see Fig.10-1). A number of other analysts, by contrast, doubt whether or not an solely limited nuclear war will occur. They believe that the initial nuclear attack will enrage both sides, and that, in conjunction with that, it will lead to the outbreak of total nuclear war. If this is the case, then both sides will take all their nuclear weapons and rain them down in torrents on the other side without holding anything back, creating catastrophic consequences.

Certain strategists in the Reagan administration are in the midst of talking about a different type of possibility which makes people uneasy in the same way: a long drawn out nuclear war. The "mutually assured destruction" strategy is based on the assumptions below--after the first nuclear attack, each side will still maintain adequate nuclear weapons. The Reagan administration is in the midst of pouring in great efforts with the expectation of obtaining a very enduring system, assuring that, under any conditions, adequate striking power will be maintained. Although the nuclear arsenals of both the U.S. and the U.S.S.R are capable of supporting a long nuclear war, nuclear butchery on a world scale is still unavoidable. Speaking

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in terms of the U.S., even if the "strategic defense initiative" achieves realization, it is possible to take nuclear bombs and repel them outside the country, however, there will still be no way to withstand radioactive contamination created by nuclear bombs. In addition, looking from the angle of true nuclear strategy, building beam weapons capable of defending against missile attacks or the capabilities of other systems is still in the midst of complications and confusion.

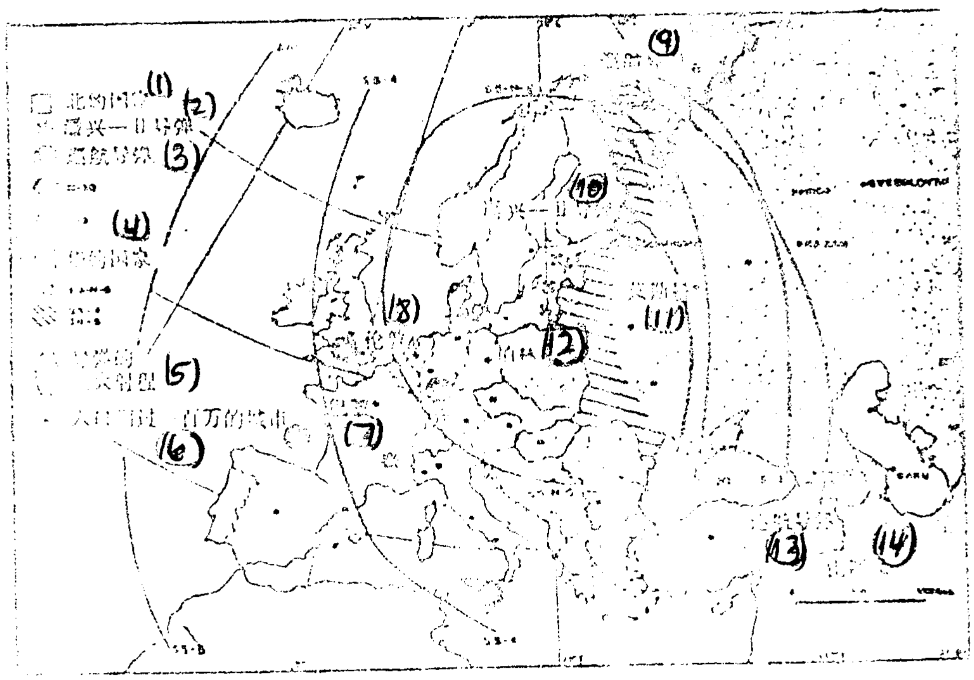

Fig.10-1 Warsaw Pact Organization (SS Series Missiles) and North Atlantic Treaty Structure (Remaining Missiles). 1981 Status of Nuclear Weapon Deployment in Europe. The reason Europeans feel insecure about the possibility of tactical nuclear war is because they are surrounded in the middle of short range nuclear weapons.

(1) NATO Nation (2) Pershing II Missile (3) Cruise Missile (4) Warsaw Pact Nation (5) Missiles of Relatively Large Range (6) Cities with Populations

Exceeding a Million (7) Paris (8) London (9) Cruise Missiles (10) Pershing II Missiles (11) Moscow (12) Berlin (13) Cruise Missiles (14) Scale

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10-4 High Technology Battlefield

Strategic nuclear weapons are perhaps the weapons in the arms race which most make people afraid. However, outlays for them are certainly not the largest. 85% of the U.S. Department of Defense budget is used in nonnuclear areas. In these are included quartermaster items and fuel supplies for delivery means. This also includes (illegible) to research and development associated with such things as complicated communications equipment, radar systems and so on. For example, the total defense budget of the Reagan administration for fiscal 1983 was 258 billion U.S. dollars. In this, 90 billion U.S. dollars were used to procure weapons. 24 billion U.S. dollars were used for research and testing of new equipment.

The complexity of tactical weapon construction and the huge outlays make people stare tongue-tied. In very many areas, the speed of their development is very quick. However, the Pentagon also complains about the time required being much longer to take a new technology and apply it to weapons systems than to apply it to industrial areas. Aidisi Mading (phonetic), former acting deputy Secretary of State complained in 1982, "At present, taking a new idea and turning it into actual equipment will take 15 years. That is twice the required time in the 1970's. As far as the time from design to production of products is concerned, half is used in engineering. The rest, by contrast, is consumed in a series of damnable bureaucratic disputes."

Tactical weapons which are capable of using new technology primarily belong to the several types of basic models below.

(I) Delivery Means This includes from jeeps to high precision fighter planes, helicopters, tanks, armored cars, warships, and groups of combat planes. Their functions are to carry soldiers or equipment to a certain place to complete specially designated missions. In U.S. military concepts, bases constructed of concrete also belong to examples of delivery means.

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(II) Weapons From rifles to heat seeking missiles, everything that is used in order to destroy enemy targets is a weapon. Targets can be weapons. They can also be people. "Antipersonnel weapons" directly kill soldiers. Other models of weapons are capable of being used in order to attack specialized military delivery means (such as aircraft) or defending against enemy weapons attacks. Of course, in that type of situation, soldiers will also be killed and wounded. However, weapons used for specialized purposes are primarily used in order to cope with tanks, warships, aircraft, and so on, but not soldiers themselves.

(III) Command, Control, Communications, and Intelligence Systems These are called simply (C3I) systems. These systems directly take information and send it to the battlefield. They include radio, radar, electric cable, direction finding systems, and systems which are capable of letting commanders in control centers know what is in the process of advancing near to them, and, on that basis, command and control the activities of their units. Due to weapons systems getting more complicated everyday, and the degree of automatization increasing, as a result,

the role of C3I systems in the area of weapons utilization is becoming unusually important. This is nothing else than why former U.S. Secretary of Defense Weinberger said this: "We are in the midst of giving C3I systems and the weapons systems to which they are matched the same serious attention. In conjunction with this, we stress an emphasis on the survivability and tolerance capabilities of C3I systems, taking the whole C3I system to act as a integral consideration." The results produced by this comment are in the fiscal 1983 budget, supplying 18 billion U.S. dollars for funding of "intelligence and communications" research.

It should be said that several billion U.S. dollars used in military research will bring very great technological progress. Because the scope of this book is limited, it is not possible to discuss details. Below, we will only give fitting explanations to a number of key technologies which must be used in beam weapons.

(I) Direction Finding Devices Just as the name itself means, they are a type of system capable of precisely determining the positions of objects. Normally, they are used to indicate the locations of enemy units. In conjunction with this, they tell beam weapons targets they should attack. Through the measurement of many parameters, direction fixing devices are capable of physical measurements of such things as sound waves or other vibrations, light, infrared radiation, microwaves, as well as radio waves, and so on, in order to complete their function. Signals in direction fixing devices must immediately be sent to another piece of analyzing equipment. The technology used by direction fixing devices as well as

back contact analyzing equipment is all very important and very complicated.

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(II) Identification Friend or Foe Systems The tasks of the systems in question grow more complicated every day due to the situations discussed below. The color of clothing worn by engaging enemy units is similar. If the clothing worn by the two sides is different, then it is relatively easy to know who attacks in the direction in question (any people who do not wear the same clothing can be very easily regarded as spies, moreover, there is a great possibility of being attacked from both sides). Speaking in terms of target identification, the role of identification friend or foe systems is unusually large. It includes distinguishing enemy tanks and certain nonharmful targets--for example, herds of cows, trees, empty houses, and so on. All the targets discussed above will appear in the fields of vision of identification systems on both sides. The Pentagon is unusually interested in the automatization of operation. However, bringing out a truly useful target identification is certainly no easy matter.

(III) Radars This is an acronym for radio detection and ranging. At the present time, this technology has already spread to broad frequency ranges. Currently, radars operate radio wave, microwave, infrared, and visible light areas. Besides measuring a target's range and bearing, precisely perfected radars are also capable of supplying some other useful information for confirming the target. Of course, when handling this information, it is necessary to be equipped with special "information processing" equipment.

(IV) Electronic Weapons Roughly speaking, they are nothing else than using electronic instruments to act as weapons, using them to supply battlefield information and interfere with enemy electronic circuits. This includes making radar and communications systems malfunction, causing weapon guidance systems and initiation systems not to play a role. In this way, enemy weapons are then not capable of hitting targets and do not have destructive effects. Electronic weapons are mostly composed of electronic opposition and anti-opposition. The full speed development and broad applications of electronic technology make electronic weapons possess very strong vitality. Military people place very high hopes on them.

(V) "Initiate and Forget" Weapons This type of weapon is capable, after initiation, of automatically running to targets, not requiring any more advanced operation by soldiers. Speaking in a certain sense, bullets are also like this. However, this type of "initiate and forget" weapon which has newly appeared is equipped with special systems. They are capable of making weapons track moving targets, and, in conjunction with that, automatically calibrate direction. At the present time, this type of automatic tracking system has still not reached the practical utilization stage. Even though this is the case, the Pentagon is still drawn toward the superiority of this type of weapon which does not need people to operate and is then capable of reaching targets. If weapons are nonautomated, the operation of soldiers then cannot avoid producing errors, making weapons unable to hit targets with high efficiency.

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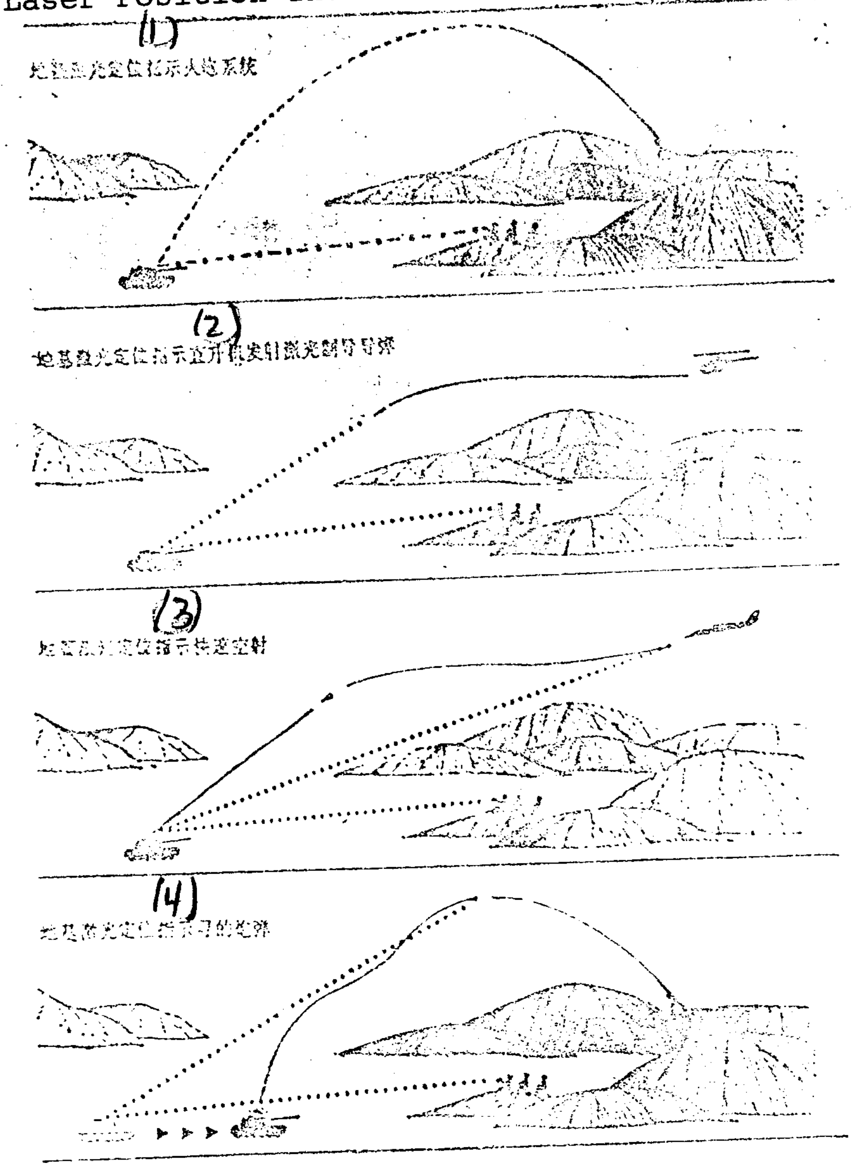
Fig.10-2 Militarily, there are many precision guidance methods. The direction shown by the dotted line is a low power laser beam indicating targets for fire power. (1) Ground Based Laser Position Indicating Cannon System (2) Ground Based Laser Position Indicated for Helicopter Launched Laser Guided Missile (3) Ground Based Laser Position Indicated for High Speed Air Shot (4) Ground Based Laser Position Indicated for Homing Artillery Round



(VI) Precision Guidance Weapons This is a type of weapon capable of active guidance in reaching targets. The earliest example was the "smart bombs" used by the U.S. in the Vietnam War. They were capable of seeking out laser reflection points on enemy targets. The reflections were completed through the use of a low power laser aiming device by soldiers on one's own side. Because this type of system has a drawback, that is, the enemy is also capable of opening fire on the soldiers carrying out the laser guidance. As a result, the interest of the military turned to "initiate and forget" weapons. Because precision guidance weapons always have higher degrees of precision than weapons without guidance, military circles, therefore, are seeing them with new eyes (see Fig.10-2). There was this kind of case. The Argentine commander in the Falklands, upon hearing that British forces were going to use laser guided bombs to carry out a raid on his headquarters, then decided to surrender.

(VII) Avionics Systems They control the movements of aircraft and the weapons they carry. In the past, this multitude of functions was completed by mechanical or hydraulic systems, but now, electronic systems have gradually gained the upper hand.

Electronic equipment is light weight and "in vogue". However, in electronic countermeasures warfare, they are very fragile.

(VIII) Guidance Systems They tell aircraft and missiles where there position is, where they should go, and how to get there. Even if they are going over very long distances, they are still able to reach satisfactory accuracies. Of course, this system is also a target that can be attacked in electronic warfare.

(IX) Ballistic Missiles Once they have gone through launching, they will fly very high above the earth. However, due to the attraction of the earth, they finally fall back to the ground. Intercontinental ballistic missiles fly in the upper layers of the atmosphere and are capable of completing very long journeys. From the U.S. to the Soviet Union only requires about half an hour. Due to their flying above the atmosphere, the use of conventional weapons to defend against them (illegible) not feasible.

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(X) Cruise Missiles They fly at low altitudes inside the atmosphere, quite close to the ground. This makes it very difficult for radar to discover them. As a result, they are not easy to defend against. As far as the determination of this type of low altitude flight path is concerned, it is necessary to have an unusual understanding of the status of terrain from the launch point to the target. Cruise missiles are capable of being launched from the air, the sea, or the ground. They are both capable of carrying nuclear warheads and also capable of carrying conventional warheads. Due to the fact that they fly at altitudes that just skim over the surface of the water, as a

result, speaking in terms of warships, they are particularly dangerous.

10-5 Weapon Technology Problems

In what direction will new technology (illegible) draw future warfare? High level military planners in the Pentagon say that they hope technology will be capable of helping win its own victory. The original chief of the U.S. Defense Advanced Research Planning Agency, Kupo (phonetic) (in office 1981-1985), said: "A new generation of advanced reconnaissance systems and precision guided weapons systems is capable of making conventional military power on the technological battlefield turn unusually fearful, leading to their being able, in the same strategies and wars, to possess the deterrent power equal to nuclear weapons."

He added: "These new weapons reach levels which are difficult for people to believe. Their significance is deep and far reaching. For the last several centuries, military commanders have right along had to rely on the possession of huge forces as well as weapons and equipment and only then could they achieve victory. However, the appearance of new weapons has changed this type of situation."

Kupo (phonetic) believes that, come the twenty first century, it is very possible that dominance in technology will win victories in war. He stresses: "This will rely on the newest types of advanced weapons associated with guidance by automatic warning management systems under water or in the air and through people directing nearby. Using the Pentagon's words, it is nothing else than weapons and warning systems which will have perfected computer systems to identify targets and, in conjunction with that, use

almost 100% hit rates to destroy them. This kind of unimaginable destructive capability will probably make the military believe that they need only sit at home waiting for victory and that will do.

With regard to this kind of optimistic military technology view point, critics bring up a number of questions. They doubt whether or not there will be that kind of hugely powerful weapon capable of blocking the outbreak of war. They see a malignant expansion in military expenditures, and this, speaking in terms of the national economy, is a heavy burden. What is particularly worthy of attention is that in certain third world countries huge military expenditures are in the midst of eating up extremely/204 limited national financial resources.

There are also some critics who firmly maintain this point of view. They believe that this type of complicated weapon will not necessarily be capable of executing missions very well. From their point of view, the more complicated weapons are, the more easily they can produce errors. The problem is not simply like that. Comparisons between weapons produced in reality and targets associated with designs beforehand will show very large differences--for example, U.S. laser guided cannons. The military, in accordance with Congressional requirements, will begin production at various times early in 1982. In 6 years of development and 2 years of production processes, a total 630 million U.S. dollars have been spent. As far as original plans to produce 44000 guns are concerned, development expenses were included. The price of each gun will exceed 20000 U.S. dollars. Military departments require that this type of gun have hit rates reaching ■ 80% for one shot (within a 16 kilometer range). If it is possible to reach this point, one or two of this type of cannon will be

capable of matching the power of several hundred conventional cannon. The actual situation is that, in tests in the middle of 1982, cannon hit rates were only 67%. This made Congress feel very disappointed. Later, due to the then Defense Secretary Weinberger's citing of the results from a number of follow on tests, it was only then that plans were made so as to continue execution.

New models of M1 tank also give rise to wide spread attention in news circles. In a report coming from the U.S. audit agency, there are complaints that this type of tank continuously breaks down. There are also a number of observers who call it unfit for anything. The "Washington Post" poked fun saying: "The M1 tank, besides being unreliable to operate, is capable of completing various other types of missions." However, military officials and a number of Congressmen, by contrast, support this project. At the present time, production of this type of tank still continues (refer to Fig.10-3).

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Jiemusi Fuluo (phonetic), in his book "National Defense", expresses concern over the Pentagon's more and more blind faith in a new generation of weapons. He suggests buying a number of simple, relatively cheap weapons and that it is not necessary to fixate only on those several types of complicated, expensive weapons. He adds, "The more complicated weapons systems are-- under bad combat conditions--the more easy it then is for them to malfunction. Moreover, once problems have appeared, soldiers then will not know what is wrong and will be unable to find any way out. Conversely, the simpler weapons are, the stronger their adaptability is. Even if malfunctions do occur, they are still easily fixed. Also, the money which the Pentagon uses in order to procure complicated weapons

can buy more of this type of simpler weapon." Fuluo (phonetic) certainly is not the only person to pay attention to these types of phenomena. Designing weapons with somewhat more functions then leaves people breathless at the expense. Although, inside the Defense Department, it seems there are a number of people who approve of Fuluo's (phonetic) point of view, there are, however, no traces at all of wanting to change the current situation.

There is another type of trend: weapons designers are more and more infatuated with the advanced nature of technology. However, with regard to weapons users, less and less consideration is given to the relationship between soldiers and weapons. Fuluo (phonetic) cites as proof that, if a certain type of weapon is not welcomed by soldiers, then, it will necessarily be discarded. Besides this, with regard to laser initiation systems, people are also very deeply concerned. This type of system requires operators to stand in a position which forms a straight line to the target in order to make laser energy, which advances in a straight line, hit the target (such as tanks).

However, doing this also makes soldiers expose themselves to the enemy, and they can be very easily attacked.

Fig.10-3 M60A3 Tank Driver's Compartment. This type of tank makes use of high level hardware and advanced initiation and control systems. The systems in question use lasers to help guns aim at targets. In the Fig., the driver is just in the midst of looking at initiation and control systems. The M60A3 is still not considered the most advanced U.S. tank. At the present time, the most advanced tank is the model M1.

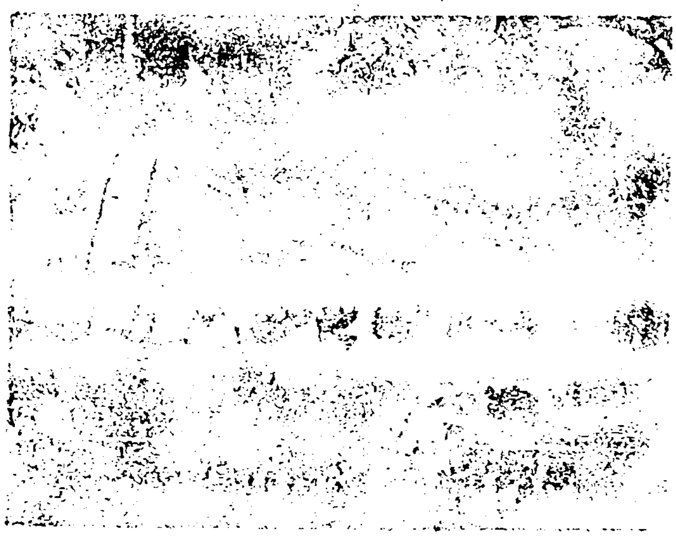

Figure 10-3

There are also a number of more subtle problems. They involve Pentagon strategy. In certain areas, they are attempting to use technological superiority to offset the numerical superiority of the Soviets. Keeping technological superiority requires maintaining secrecy from the Soviets. This is certainly not easy to do. The reason is that, a number of technologies involved in complicated weapons systems will also be used in other areas. In those areas, the principles of secrecy do not play a role. For example, in the U.S., Japan, and many western European countries, it is possible to commercially offer for sale precision electronic circuits. These are very useful in missile guidance and initiation.

U.S. government officials firmly believe that the Soviets are in the midst of racking their brains to obtain U.S. technology by every possible means. In order to make key military technology not be leaked to the Soviet Union, the U.S. and a number of allied countries have strengthened controls on export of technology. However, what the effects of doing this will be in the end still leave people

doubtful. The reason is that this type of technology is capable of being obtained from other countries, and, there, export controls are certainly not strict. A number of U.S. business people complain that the results of this type of control are to take the Soviet Union as a customer and give it to such nations as Japan and France, attacking U.S. industry. Moreover, in reality, it certainly does not block the Soviets from acquiring this type of new technology.

The U.S. Defense Department wants to apply sanctions to the problem of papers at academic conferences leaking secrets. The U.S. government's (illegible) export limitation laws are applicable in the same way to technology and hardware (even if this type of technology is discussed in a symposium called in the U.S.). In this way, it then makes the directions in which the technology treatises of a number of people are presented subject to limitations. This is capable of bringing with it complaints from manufacturing firms. The reason is that their operations will only be able to obtain low remuneration due to military intervention. U.S. laws are effective. However, this regulation has still not achieved recognition as law.

10-6 The Arms Race and Arms Control

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The status of military expenditures in various nations of the world cannot be accurately known. However, on the basis of statistics, in 1981, the various nations of the world made total military expenditures of 600-650 billion U.S. dollars. A number of economists believe that huge military expenditures-- speaking in terms of the economies of the U.S. and the U.S.S.R-- are an extremely heavy burden. A number of people point out that the reason why the

Japanese economy has been capable of rapid growth is primarily a very low military budget. They believe that, if one is thinking of causing a big pick up in the economy, it is, then, necessary to reduce military expenditures.

It is also possible to find very numerous reasons military expenditures should be reduced. However, stopping the arms race is easier said than done! Both the U.S. and the U.S.S.R possess huge military power aimed at the other. Both assert that the other side cannot be trusted. For these many years, practice has clearly shown that making both sides sit down in good faith to negotiate and reach arms control treaties with practical significance is very difficult!

10-7 The Effects of Beam Weapons

The technological feasibility of beam weapons is determined by them themselves. However, it is not possible to independently consider one type of weapon in terms of military significance. It is very clear that the development of beam weapons is a product of the arms race. This is particularly due to the fact that they are capable of defending against nuclear attacks. Beam weapons can perhaps give military strategists new ideas. Technologically speaking, beam weapons are different from the majority of military weapons currently existing. Certain beam weapons are unusually suitable to strategic defense or use on the battlefield.

In accordance with the statements of U.S. officialdom, beam weapons will be used in strategic defense. However, beam weapons will actually be lethal offensive weapons. The U.S. physicist Kaluolin Hecengboge (phonetic) of the

Arergong (phonetic) National Laboratory says that laser casualty effects include the ability to melt the outer shells of enemy missiles. It is also possible to melt the outer shells of other relatively thin targets--for example, strategic bombers, airborne command centers, ships, cruise missiles, and so on.

She says that lasers are actually a type of potential burning weapon. Space defense systems possessing laser emission sets numbered in the hundreds are capable of starting large destructive fires in cities.

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Chapter XI DEFENSE FROM NUCLEAR ATTACK

Today, the strategic military balance of forces between the U.S. and the U.S.S.R is set up on the foundation of nuclear terror. It is an extremely unstable balance. The nuclear weapons arsenals of the U.S. and the U.S.S.R are both adequate to destroy the other side several times. The strategy of "mutually assured destruction" is maintaining a risky world peace. At the present time, there is no side which dares to initiate an attack first. The reason is, even if a nuclear attack is suffered, the attacked side still has adequate nuclear power to wipe the attacker off the face of the earth.

President Reagan calls for the development of a strategic ballistic missile defense system. The object is to discard the strategic policy of "mutually assured destruction" and replace it, setting up a new strategy, that is, depending on defensive capabilities to make the enemy unable to exert the effects of the weapons they had put their faith in and no longer reliant on the deterrence of attack capabilities. In this type of military strategy, there is an undeniable philosophical attraction. Reagan, when he ended his 23 March 1983 speech, said that he would organize a broad, in depth, demonstration in order to firmly establish a long term research and development plan to eliminate the threat associated with the production of strategic nuclear missiles--in conjunction with this, opening up a route to the elimination of weapons themselves.

Reagan's critics believe that strategic defense is a very far off condition, even to the point of being impossible to actually realize. They warn: "Any attempt to think of moving away from the present "mutually assured destruction" posture could also be an extremely dangerous destruction of the military balance of power." They also say that Reagan's proposals are the results of efforts to carry out (illegible) nuclear "warriors" in the administration for the U.S. to be able to (illegible).

Directed energy weapons are an important part of ballistic missile defense plans. Despite the fact that they only occupy 1/3-1/4 of the expenditures used on ballistic missile defense at the present time, their attractiveness to the military, however, cannot be doubted. This is because they are capable of rapidly hitting targets at very great distances. For example, after ICBM's fly out of the atmosphere, they are capable of intercepting them during high speed flight. Also, there are a number of targets--for example, bombers flying long missions at extremely high altitudes, nuclear missiles launched from under water, and so on--that are also targets directed energy weapons intercept. With regard to time intervals for introduction into use of missile defense systems equipped with beam weapons, estimates associated with various areas differ very greatly. Proponents of beam weapons in the Reagan administration hope, in the year 2000--and there are those people who are more optimistic--hope to be able to build beam weapon systems within ten years. However, outside the Pentagon, a number of people holding pessimistic attitudes, by contrast, tend toward the idea of giving that up and making beam weapons play their role within a few decades from now, even to the point of believing that the entire idea cannot be actualized.

11-1 Missile Defense Theory

Technological difficulties in ballistic missile defense are determined by the nature of defense itself. The volumes of targets defended against are very small. Moreover, their speeds are very fast. This is particularly true of attacking nuclear missiles. Theoretically speaking, attacking missiles are capable, along their movement tracks, of being attacked and destroyed at any point, that is, attacking missiles penetrations of outer space as well as quick penetrations through the atmosphere, before they have yet reached the target, they are capable, in all cases, of being destroyed (see Fig.11-1). However, when one attacking missile launches numerous warheads, the problem then becomes complicated. These warheads are capable, after launch, of separate guidance. Speaking in terms of defense systems, they then become numerous interception targets. In reality, thinking of hitting them on the flight paths of missiles and warheads still poses a great many technological difficulties.

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Beginning in approximately the 1960's, the U.S. did research on and exploration of the idea of ballistic missile defense. However, due to the fact that, at that time, space technology was still in the developmental stage, the primary attention was only capable of being placed on destroying missiles when they approached targets, that is, destroying them before they reentered the atmosphere or during rapid descent in the atmosphere. Early Nake (phonetic) - X projects finally developed into a defense system, and, in the middle 1970's, was put into service near U.S. missile bases in the state of North Dakota. However, it is very far from the nuclear defense system put forward by the Reagan administration.

This type of defense system is composed of large model precision tracking radars and two types of defensive missiles. Large model Sibatan (phonetic) missiles carry a nuclear warhead. They are capable of flying several hundred kilometers and can, outside the atmosphere, destroy attacking missiles. Small model Sipulinte (phonetic) missile ranges are very short--only capable of defending within a range of 16 kilometers. This is nothing else than the first case of "layered" defense. In nuclear attacks, attacking missiles which slip through to the second layer of defending missiles can have interception carried out by the second layer.

In 1971, the Pentagon devoted its efforts to another type of missile defense system. It was dedicated to protecting Minuteman missile bases. These bases, after going through hardening, are adequate to withstand a nuclear explosion in the vicinity. This

defense plan uses improved Sipulinte (phonetic) missiles to carry out low altitude defense. The completion of the plan in question (deployment completed in September 1980) made the Pentagon

understand a number of things it did not know in 1975.

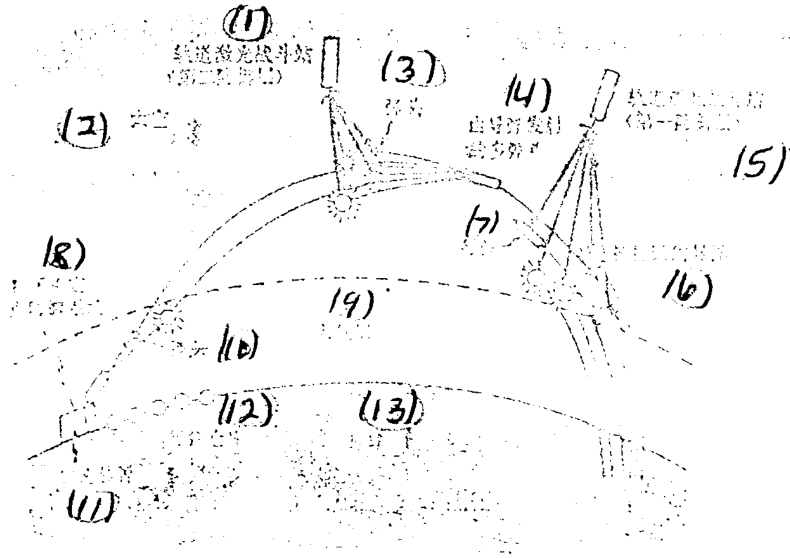

Fig.11-1 The basic intention associated with setting up a "multilayer" missile defense system is to destroy enemy missiles entering the defensive fire network. Missiles, in the process of flying through the atmosphere, will be attacked by laser combat stations. Missiles not yet destroyed by the first defensive layer launch a number of warheads returning into the atmosphere. These warheads will suffer second defensive layer space station attacks. As far as warheads surviving down through this layer are concerned, they will face attacks from fixed point defense of

strategic targets such as missile storage sites. The primary theoretical foundation is that, even if single layer defense systems are not capable of destroying all incoming missiles (warheads), various defensive layers combined together, however, form a multilayer defensive system. Generally speaking, it is possible to destroy the overwhelming majority of incoming missiles (warheads). This mode is based on the assumption of opting for the use of laser and particle beam technologies. However, in theory, other types of defensive systems are also capable of being applied in outer space or on the ground.

(1) Orbital Laser Combat Station (Second Defensive Layer) (2) Space (3) Warhead (4) Multiple Warheads Launched from Missiles (5) Orbital Laser Combat Station (First Defensive Layer) (6) Destroyed Missile (7) Missile (8) (Illegible) (9) Atmosphere (10) Warhead (11) Acceleration System (12) Missile Storage (13) Earth
defense safety systems were deployed.

In this time period, strategic arms control talks had achieved definite results. The antiballistic missile treaty signed in 1972 limits the U.S. and the U.S.S.R to only being able to set up two missile defense systems: one in the vicinity of missile launching sites and another in the vicinity of the capitals. A 1974 treaty stipulated anew that each country could only have one antimissile system. The U.S. decided to protect its North Dakota missile launch bases. The Soviet Union, by contrast, set up an antimissile system in the vicinity of Moscow.

In 1976, the U.S. believed that antiballistic missile defense systems have no value in practical use. Because of this, even this one antimissile system was also discarded. They believed that antiballistic missile defense systems themselves had problems. High precision tracking of launched missiles required large model complicated radars (this type of radar is easily destroyed). If radars have been destroyed, antimissile systems then also become junk. Defensive missile reactions must be very quick. However, accelerating them to the required speeds, in the final analysis, requires time. When nuclear warheads explode, they will produce very strong electromagnetic pulse effects within very large ranges. This type of effect is adequate in order to make defense safety systems suffer destruction or destroy other weapons systems. /212

The defense safety discussed above is limited only to protecting missile bases, and, in reality, protecting one missile base will be much easier than protecting cities. The reason is that missile bases, after going through hardening, are capable of withstanding nuclear explosions in their vicinities. One Minuteman type missile launch site is capable of withstanding 680-1361 atmospheres pressure. However, cities and other

populated areas are capable of withstanding much smaller pressures by contrast. Antiballistic missiles are capable of detonating the warheads carried by reentry vehicles or detonating their own nuclear warheads. For a city to be able to luckily survive through a nuclear explosion, the attacking nuclear warhead must detonate outside 14-23 kilometers. However, when a bomb of the same power explodes outside 370-460 meters from a missile base, the hardened missile base will also not sustain severe damage. Of course, the safe ranges above ignore the long term effects of radioactive fallout.

Fig.11-2 Schematic of a U. S. MX or "peacemaker" Antiballistic Missile Launch Silo

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The Pentagon right along devoted efforts to studying a type of new model ground missile defense system, that is, low altitude defense. The aim lay in making technological preparations for MX missile base defense (see Fig.11-2). Military personnel believe that, in order to make this type of missile capable of surviving during opposition attacks, it is necessary to have this type of defense. The Pentagon and the Congress have already agreed to establish this type of MX missile at a certain place.

The originally stipulated project plans require making use of radars of appropriate power. Moreover, nuclear warheads are installed on the defending missiles. The reason is that nuclear

warheads have relatively great power when destroying delivery means as they reenter the atmosphere. Pentagon officials estimate that, in future, there will be a 50% probability of developing an appropriate non-nuclear warhead. In this way, it will then be possible to avoid electromagnetic pulses and radioactive fallout. Military designers attempt to avoid making precise estimates of the state of costs associated with the setting up of MX missile defense systems. The roughly calculated expenditures are 10-25 billion U.S. dollars. It is hoped, through deterrence, to block attacks of long range Soviet nuclear warheads on the U.S. However, these expenses are only capable of indirectly protecting peaceful inhabitants. Seen logically, this is inappropriate. However, this is precisely the intent of defense strategy.

11-2 Space Based Defense Systems

Military analysts inside the Pentagon as well as outside have already given their consideration to it, and they primarily point toward the fact that ballistic missile defense systems should, in part or wholly, be installed in outer space. Despite the fact that, technologically, it is not very easy, this type of thinking is, however, very attractive. Space based defense systems can protect cities. They are also capable of protecting hardened military bases. The reason is that they can destroy nuclear warheads in space very far from cities. In multilayered defense systems, it is also possible to consider opting for the use of even more layers.

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Space based defense systems certainly do not necessarily have to rely on beam weapons. The U.S. has an organization called "High Frontier" (this organization is primarily composed of retired military officers and space development volunteers). It put forward an enormous plan utilizing missile weapons. As far as the "High Frontier" proposal relating to a global

ballistic missile defense system is concerned, it includes an array of orbiting "gun carriages". On each "gun carriage" there are 40-45 attack delivery means. 432 "gun carriages" move in orbit 560 kilometers from the earth. The angle of inclination relative to the equator is 65° in order to make "gun carriages" capable of covering most of the area of the Soviet Union. Each attack delivery means has on it a delivery rocket in order to accelerate the attack. Speeds of delivery means relative to "gun carriages" reach 1 kilometer/sec. This type of casualty producing means does not require nuclear explosions to destroy targets but relies on shock forces.

Targets that this type of system are aimed at are missiles in the ascent propulsion phase. In this phase, missiles have still not launched warheads. They have also still not thrown out a number of false warheads to multiply the targets. This "High Frontier" proposal requires placing a good number of defensive satellites in orbit in order to guarantee there always being some satellites positioned above the Soviet Union, making it possible, whenever necessary, to fire back on a missile offensive. After going through the first layer of interception, the numbers of attacking missiles in orbit are reduced. Warheads and decoys that have penetrated the first defensive layer and been launched from missiles will, when flying in space, be destroyed by other casualty producing weapons placed in outer space orbit over the territory of the Soviet Union. Hitting this type of target will be much more difficult than hitting missiles in the boost phase. This type of interception will reduce a step further the numbers of attacking missiles.

Besides the systems discussed above, there are also a number of ground systems to carry out special defenses of some particularly important installations--for example, missile launch bases and so on. The preliminary notion associated with handling this type of offensive is to launch approximately 10000 small

rockets. These small rockets rapidly reach velocities of 1.5 kilometers/second and, through mutual collision methods, destroy the attacking missiles. In the beginning of 1983, "High Frontier" spokesmen expressed the view that this portion of the contents had some things to be changed. "High Frontier" proposes not to launch groups of small rockets any more, but use gatling gun systems. Because they can fire rapidly, they produce a "wall of bullets" in the vicinity of ground targets. It is said that use has been made of similar gatling guns in order to defend against air raids on warships. However, looking from the standpoint of the limited war situations of the last few years, the defensive results are certainly not very good.

People putting forward "High Frontier" research believe that their method is one type of "outflanking" method. This type of method will make the U.S. take the lead over the Soviet Union. In conjunction with that, they say that there is a possibility to use "modern equipment" to set up a ground defense system. This system will be adequate to protect ICBM's in missile storage, avoiding utilization of MX intercontinental ballistic missiles with high construction costs. An initial global space ballistic missile defense can be built within five or six years.

11-3 Layered Defense Evaluation

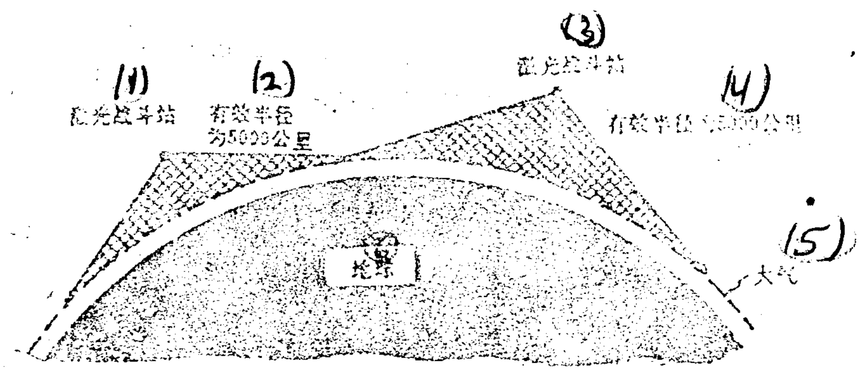
Multilayered defense, as compared to single layer defense, possesses greater potential (refer to Fig.11-3 and 11-4).

First, generally speaking, several layers of medium efficiency defense systems taken together are always more efficient than a single layer defense system with the same type of efficiency.

Second, theoretically speaking, multiple layer defense systems are more sound than single layer defense systems--in

particular, when various layers utilize different technologies and opt for the use of different design plans.

Fig.11-3 Schematic of Laser Combat Stations Sealing Off the Entire Earth. If the range of each laser (illegible) 5000 kilometers, then, they can rapidly destroy any missiles launched in the shaded areas of the diagram. A number of lasers cover overlap areas and will be placed on the side belts of laser combat stations. No matter how the distance of missiles from laser combat stations and flight altitudes change, they are all within range of laser combat stations. (1) Laser Combat Station (2) Effective Radius is 5000 Kilometers (3) Laser Combat Station (4) Effective Radius is 5000 Kilometers (5) Atmosphere (6) Earth



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Third, initial period--booster phase and post booster phase defense--reduces the responsibilities of later period defenses. If half the incoming missiles have already been destroyed in the initial period, then, middle period defense systems will only face attack from small numbers of missiles.

Fourth, multi-layer defenses permit designers to give each layer's system unique capabilities. For example, multi-layer defenses are capable of having two different booster phase and

middle period methods of interception. However, single layer systems are only capable of selecting one type from among them.

Despite the fact that layered defenses have the advantages referred to above, there are, however, a great many drawbacks existing. The clearest problem is that the construction cost of four layers is far, far higher than for single layers. In situations where the four layers are mutually independent, this is particularly the case. Secondly, the four layers combined together, have an overall efficiency determined by the defensive capabilities when the various layers stand alone. If the various layers depend on the same sensor system, when the sensor system

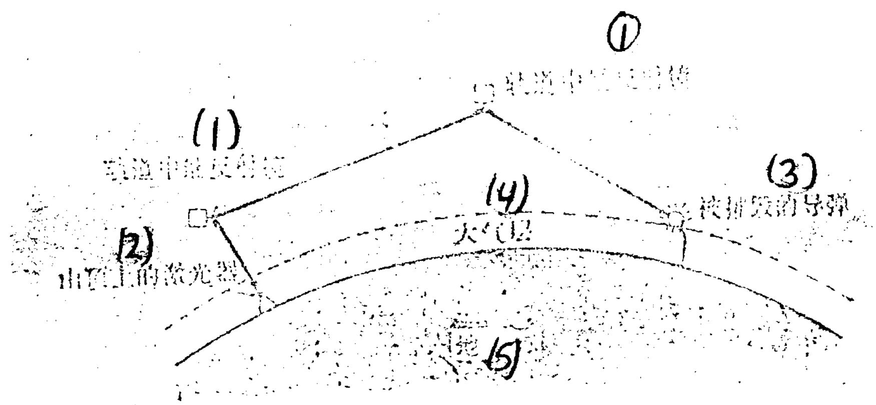

Fig.11-4 Taking the most unwieldy parts of laser weapons and putting them on the ground, let lasers go through the atmosphere, and it is then possible to hit targets. However, this means that laser beams must pass through the atmosphere and be interfered with. This schematic diagram represents how laser light emitted from a mountain top laser passes through two intermediate (illegible) reflecting mirrors and, after focusing, destroys a missile. Laser beams being reflected from one mirror to another mirror require the most modern control systems. Moreover, it also requires multiple reflecting mirrors. The reason is that the speeds at which reflecting mirrors in orbit move are very fast, making them very quickly break away from laser beams emitted by base lasers. Despite the fact that these several problems remain, due to this solution, however, it is possible to avoid taking unwieldy laser devices and transporting them into orbit. As a result, it gets serious attention. (1) Orbital Relay Reflecting Mirror (2) Laser Device on Mountain Top (3) Destroyed Missile (4) Atmosphere (5) Earth

in question malfunctions, the various layers of defense systems will all become junk (that is, turn into "deaf people" or "blind people"). However, if each layer is completely independent, then, the overall penetration rate can be multiplied out through the penetration rates of the various layers. Otherwise, forward layer defense system penetration would then not be able, from follow on systems, to get full supplementation.

System fault prevention capabilities depend on how much the price of expenses is in order to compensate for this fault. Each layer of defense system must accomplish the utilization of the strong points of other layers to defend systems, but not excessively rely on them. For example, if the boost phase and post boost phase both let twice the anticipated number of warheads through the defensive layers, in that case, it will then lead to a drop in intermediate defense system recognition and interception capabilities. It will not only let non-predetermined warheads through, it will also let many warheads, which are not easy to intercept, penetrate.

In actual situations, before the fact, it is not possible to know for certain the effectiveness of any one layer of defense. Moreover, with regard to predictions of real combat capabilities, there also exist a great many undetermined factors. However, as far as the two areas of attack and defense are concerned, there are big differences in knowledge associated with these indeterminate factors. Considering from the angle of defense, in order to prevent a number of systems not be able to reach predicted defensive targets, it is necessary to make them (or other systems) possess supplementary functions. However, considering from the angle of the offensive, indeterminate factors, by contrast, will make their credibility at destroying (or penetrating) defensive systems reduced.

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The requirements associated with defensive capabilities and targets defended against are related. With regard to intercontinental ballistic missiles, 40 and 50% effectiveness rates only produce very small differences. The reason is that, if the purpose of a defensive system lies only in providing survival capabilities, and, in conjunction with that, creating a certain deterrence with respect to the enemy, and it is not to protect cities and inhabitants, then, it is of no importance even if only one weak defensive layer exists. However, city defense efficiency rates of 90% and 99.9% still cause 100 fold differences in warheads reaching U.S. cities. This will give rise to the two sharply different results of survival or destruction.

Each layer of defensive system requires the completion of the missions listed below:

(I) Monitoring and Detection Surveying the number and launch points of enemy warheads attacking and precisely determining the targets capable of being attacked.

(II) Resolution Correctly differentiating missiles, warhead mother compartments, warheads, and harmless decoys, as well as other fragments.

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(III) Command and Tracking Precisely tracking enemy reentry vehicles and transmitting information to defensive weapon system command centers in a timely manner.

(IV) Destroying Targets Defensive weapons should be able to rapidly release adequate energy to destroy reentering enemy targets.

(V) Casualty Estimation Appraising and identifying destroyed targets as well as targets still surviving. If it is possible to precisely determine the cause for a certain target's warhead still not being destroyed (for example, guidance malfunction), this will then produce benefits in preventing later offensives.

Fulfilling the tasks above requires information processing and power source supplies to act as backup. As far as sensors used in collecting information as well as target emitted (or reflected) beams are concerned, this information stores characteristics data associated with various individual targets. Sensors and data processing technology play decisive roles with regard to ballistic missile defense. After weapons systems identify and confirm targets, energy stored in weapons systems must then be turned into special forms of adequate power to shoot at targets, with the objective of reaching and destroying the targets. Various forms and types of directed energy (beam) weapons as well as kinetic energy weapons will all play this role.

11-4 The Actual Military Power of the Soviet Union in Outer Space

Although the Soviet Union lags behind the U.S. in such areas as its economic foundation and real economic power as well as the levels of cutting edge science and technology--due to its early start in spaceflight technology and the plentiful resources and manpower put into it, however--as a result, it surpasses the U.S. not only in the number of spacecraft deployed each year as well as in effective lifting weights, but also takes the lead over the

U.S. in the area of actual combat preparations for outer space warfare.

I. The Soviet Union's Satellite System and Antisatellite Weapons Systems

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In March 1962 the Soviet Union formally launched a series of military satellites called "Cosmos". Beginning in 1968, the Soviet Union's military satellite launches were unusually frequent. In 1968 the U.S. launched 38 military satellites. The Soviet Union 44. In 1969-1970, the Soviet Union deployed 102 military satellites. The U.S. only 45. (illegible) to 1976, the U.S. launched 180 military satellites. The Soviet Union launched 492. In 1977-1983, the U.S. launched a total of 117 military satellites. The Soviet Union, by contrast, reached 1129.

The Soviet Union not only occupied the dominant position in terms of numbers. Moreover, the military satellites showed very great improvements in types and capabilities. Up to now, the Soviet Union has already developed and deployed overall type photo reconnaissance satellites, detailed photo reconnaissance satellites, weather satellites, and three types of communications satellites such as earth orbiting communications satellites, and 24 hour orbit but nonsynchronous communications satellites, as well as synchronous orbital communications satellites, and ten or twenty new models of military satellites such as navigation and guidance satellites, ocean monitoring satellites, interception satellites, electronic reconnaissance satellites, early warning satellites, manned reconnaissance spacecraft, radar reconnaissance satellites, nuclear explosion detection satellites, and radio storage and transmission satellites. Among these, oceanic monitoring satellites are used in order to reconnoiter and monitor enemy navy vessels--particularly as a key tool associated with nuclear submarines. At the moment, Soviet

reconnaissance satellites--the same as the U.S.--possess resolution capabilities for ground targets of 0.5-0.6 meter sizes. Moreover, "One Arrow Eight Stars" technology occupies a leading position in the world.

Development of Soviet antisatellite weapons systems began in 1967. Beginning from 1968 until the present, more than 20 antisatellite tests have been carried out. Tests basically opt for the use of interceptor satellite launches after discovery and tracking of targets. After that, they are made to maneuver and change orbits, instantaneously approaching targets in order to launch such casualty producing weapons as steel balls, rockets, and so on, or making use of methods of self-destructing into fragments with the purpose of reaching and destroying targets.

In February, 1976, the Soviet Union began carrying out actual antisatellite combat tests. In June of the same year, the Soviet Union launched 918 interceptor satellites. They surrounded the earth in low orbit in several rings. After that, urgency increased. They successfully destroyed a No.909 target satellite in quasisynchronous orbit with an apogee of 2103 kilometers and a perigee of 994 kilometers. In 1977, the Soviet Union used one SS-9 carrier rocket to launch 4 interceptor satellites. Interception was carried out of 3 target satellites launched using one SS-5 carrier rocket several days before, and success was achieved.

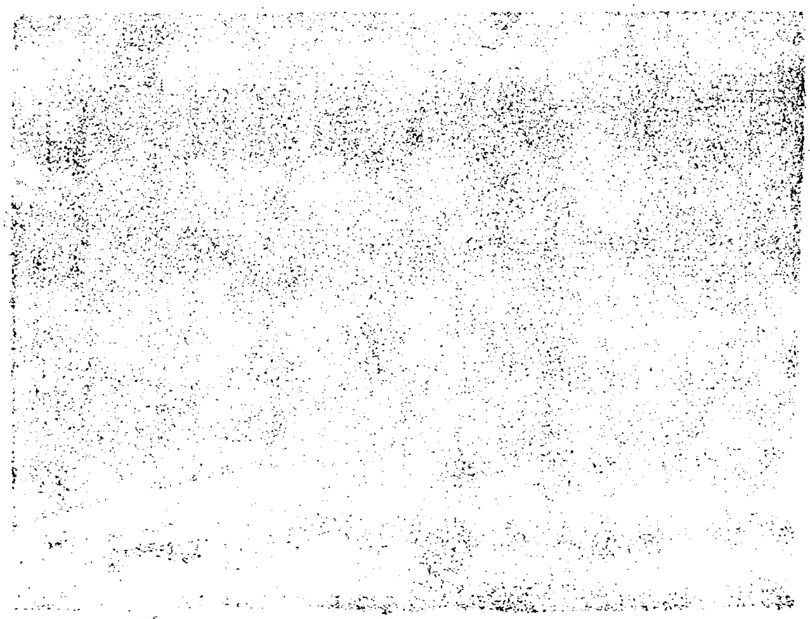 /220

Fig.11-5 Schematic of Manually Controlled Space Shuttle Attacking Satellite

Beginning in 1980, the Soviet Union began to carry out real antisatellite combat tests. In June of 1982, the Soviet Union launched the Cosmos No.1397 interceptor satellite. The satellite in question used an interception method of launching "steel balls densely concentrated like rain", successfully destroying the Cosmos No.1375 target satellite. In the next year, the Soviet Union also employed a similar method, successfully destroying an artificial satellite traveling in space over the Federal Republic of Germany. This was an actual antisatellite combat test carried out by the Soviet Union outside its own air space--possessing important significance for actual combat.

Although Soviet antisatellite weapons systems still have a great many limitations, the U.S. Defense Department, however, believes: "The Soviet Union possesses the world's only known antisatellite system capable of use in real combat." /221

II. Antiballistic Missile Systems and Directed Energy Weapons

The primary intention of the Soviet Union in setting up antiballistic missile systems lay in destroying as much as possible incoming attacking nuclear missiles in a nuclear (illegible) exchange in order to defend their own head agencies and preserve their nuclear counter strike capability. Up to the present time, it has become the world's only nation possessing on hand antiballistic missile systems for real combat.

The Soviet Union's antiballistic missile system primarily includes antiballistic missiles and warning systems.

In 1980, the Soviet Union, in the environs of Moscow, deployed 8 launch sites of 4 missile bases with 32 improved ABM- 1B "Rubber Overshoe" antiballistic missiles. Their range is over 320 kilometers, and they are equipped with nuclear warheads rated in the megaton range. They are capable of making use of nuclear explosions carried out beyond the atmosphere. In the future, attacking missiles and false targets released by them will be completely destroyed. Moreover, they are capable, within two hours after firing, of reloading missiles and firing again. As far as the new SA-10 and SA-X-12 models of ground to air missiles, recently developed and fielded in units, are concerned, the ranges are all over 100 kilometers. They are both strategic air defense missiles and antiballistic missiles. They possess the capability to destroy the U.S. "Lance" types, Pershing-I type, and Pershing-II type tactical nuclear missiles, as well as certain strategic nuclear missiles.

Warning systems primarily include satellites, warning radars, and ground control intercept radars. Their functions are detection, identification, and tracking of incoming attacking missiles, and, in conjunction with this, sending down combat commands to antiballistic missile launch sites.

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In outer space high elliptical orbit, the Soviet Union always maintains two or more quasisynchronous detection and warning satellites. They can immediately send out intelligence data to the ground on the initial stages of the U.S. launching a nuclear attack. At the same time, the Soviet Union has deployed, within its borders in 6 districts, 5 "rooster" series radar stations for a total of 11 large model, long range warning antiballistic missile radars. Their detection ranges in all cases are over 6000 kilometers. They are capable of identifying and tracking incoming attacking targets from northeast, southeast, westerly, and southerly directions. Besides that, the Soviet Union, at the present time, is in the midst of intensifying the deployment of phase control array radar in Abala(illegible)wa in a total of 10 stations. It is estimated to possess the capability "to track several thousand incoming warheads at the same time". It and "gowo" and "maowo" type medium range radars with detection distances of 3000 kilometers, and "shijia"
type antiballistic missile control radars, as well as the 7000 plus sets of various types of radars associated with the over 1200 districts within her boundaries not only already completely cover Soviet territory. Moreover, in a number of districts, the coverage areas already deeply penetrate neighboring countries by several hundred kilometers. The disarmament question spokesman Yuergen Tuodenghefeier of the Federal Republic of Germany's Premier Keer coalition party, in the summer of 1985, pointed out: "Within 3-4 years, it (the Soviet Union) will then be able

to protect all their large ICBM's and other important military installations."

As far as the development of directed energy weapons such as high energy lasers and particle beams which possess strong antisatellite and antimissile capabilities is concerned, it is the main development direction associated with the Soviet Union's carrying out of actual outer space combat preparations. According to reports, the entire decade of the 70's, total expenditures on Soviet development of directed energy weapons was higher than 10 billion U.S. dollars. That is over 9 times the U.S. expenditure of 1.07 billion U.S. dollars on the development of directed energy weapons in the same period. After the 1980's, the U.S. increased expenditures on the development of directed energy weapons. However, the Soviet Union is still 3-4 times that. From the 1970's onward, the Soviet Union throughout has had more than 10,000 scientists and engineering technology personnel engaged in development work on directed energy weapons at over 100 laboratories and research bases all over the country, such as, Lieninggele Saluowa and Saimibalajinsike and so on.

Early in 1968, the Soviet Union then basically completed technological designs for such things as laboratory particle beam emission, adjustment, and control. In 1974, electromagnetic induction accelerators emitting particle beams and pulse linear accelerators, as well as such auxiliary equipment as special X ray instruments, 6 frequency channel ultra high voltage switches and magnetic storage generation devices had already been developed successfully, and, in conjunction with that, linked together to form sets. Beginning from the end of the 1970's, the Soviet Union, at Saluowa and Saimibalajinsike experimental bases, successfully carried out numerous iterations of the destruction of aluminum alloys using particle beams as well as carrying out nuclear fusion experiments. /223

The Soviet Union's high energy laser weapon technology development was even faster. Before 1975, what the Soviet Union mainly carried out was basic research associated with pulse nuclear explosions needed to produce high energy lasers. In conjunction with this, on the foundation of multiple interations of experiments, the nuclear physics of X ray lasers using nuclear explosions to drive them was established. After the middle of the 1970's, the Soviet Union's high energy laser weapons entered into engineering development and the test manufacturing phase for concrete weapons systems. Beginning in 1975, at Saimibalajinsike experimental base, the Soviet Union carried out a total of 7-9 underground nuclear explosions. In all cases, the high energy electromagnetic pulses required for the emission of X rays were successfully obtained. In 1979, the Soviet Union used laser weapons to successfully destroy surface targets. In 1981, experiments with lasers hitting targets were carried out on missiles in flight and again success was achieved. At the present time, the Soviet Union is in the midst of developing a type of new model laser weapon system used against satellites and against ballistic missiles. In conjunction with this, they plan, within two years, to launch it into orbit. "The Secrets of Super Weapons" recognizes that the Soviet Union leads the U.S. 3-10 years in the area of directed energy weapon development. In particular, the Soviet Union's change over to the practical application of laser weapons has already become a possibility. They "are adequate to destroy enemy missile warheads."

III. Outer Space Stations and Space Planes

Outer space stations possess the functions of reconnaissance, command, and combat centers. They are important contents of the Soviet Union's preparations to carry out actual combat in outer space.

On April 19, 1971, the Soviet Union launched its first outer space station "Salute No.1". After that, it also launched "Salute No.3" and "Salute No.5" specializing in the execution of military missions, as well as the dual military and civilian purpose "Salute No.4", "Salute No.6", and "Salute No.7". At the same time, there were also launches of over 50 "Union" series and "Union T Model" manned space ships, as well as over 20 "Progress" series space freighters. Rendezvous and docking were carried out with "Salute" series space stations. Through "Salute" series space stations, the Soviet Union accumulated important experience associated with the carrying out of various types of military activities on space stations. As a result, the foundation was laid for the establishment of a permanent space station. On 29 September 1977, in the launching of "Salute No.3", over 50 types of instrumentation and equipment were installed to carry out research and experimentation. In this space station, Soviet cosmonauts carried out a total of over 120 space processing science experiments relating to such things as weather, biology, medicine, the refining of high purity crystalline silicon, and so on. They took more than 10000 photographs. At the same time as this, Soviet cosmonauts, during a flight going around the earth more than 3000 times, used cameras associated with more than 6 wave bands of optical spectra and other instruments and equipment to carry out electronic and photographic reconnaissance of the whole territory of the U.S. and its territorial waters, picking up large amounts of military intelligence. In the 1980's, the Soviet Union plans to launch space stations capable of carrying 10-25 cosmonauts. In the 1990's, they will launch Salute series space stations capable of carrying 120 cosmonauts.

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At present, the Soviet Union possesses "Power Source" model rockets with the largest useful loads in the world. "Power Source" rocket prices reach 20 billion pounds sterling. They are 200 English feet high and are capable of lifting weights

equivalent to 9 U.S. space shuttles. Their 8 main motors are capable of producing thrusts of 170 million horsepower. In terms of technology, they are far, far in the lead over any Western rocket motor. According to reports, the rockets in question have already successfully carried out test flights.

The Soviet Union most recently announced a plan that will launch an unmanned space ship to Mars in 1992 to collect samples.

In accordance with this plan, at the same time the Soviet Union is in the midst of launching the space ship, it will also launch scientific equipment and apparatus weighing 27 tons, as well as automated cross country vehicles walking across the surface of Mars. This type of cross country vehicle makes use of nuclear fuel. It is capable of walking 250 English miles. After collecting samples, a transportation rocket is sent back. In it a number of instruments will have bore into interior layers of Mars, collecting samples and data. On the Martian surface, probes will spend periods of several months. After the plan is completed, samples will be launched back to a space ship flying around Mars and be sent back to Earth.

From the above it can be seen that the Soviet Union is already in the leading position in the area of space stations.
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In outer space warfare, space shuttles are not only means of communication and transportation. They are also command centers and combat weapons for the carrying out of strategic attacks. Compared to the U.S., at the present time, the Soviet Union is still in an inferior position in this area. However, Soviet space shuttle research and development possesses a considerable technological foundation and potential. Since April of 1967, the Soviet Union has used A-2 model rockets to launch dozens of

"Union" series manned space ships. In actuality, these already possess the qualities of small space shuttles.

Chapter XII OPPOSING SATELLITE WEAPONS

As far as beam weapons which are capable of being used in nuclear weapons defense are concerned, at the present time, it seems that they are still relatively far off. However, antisatellite beam weapons, by contrast, will go into practical use relatively quickly. The U.S. side believes that the Soviet Union has been exerting its efforts right along to develop antisatellite laser weapons. A few years ago, a joke appeared relating to Soviet development of laser weapons. At the end of 1975, a U.S. spy satellite observed very strong infrared radiation coming from the Soviet Union. The Pentagon took this and interpreted it as meaning Soviet laser tests. However, they later learned that it was a natural gas fire in a certain Soviet location. It seems that the Americans maintain an alert about this right along. In 1983, "Aviation Weekly" reported that, on the basis of analysis, "enemy" lasers were responsible for the malfunction of a U.S. Air Force spy satellite a few months before. In actuality, this is difficult to confirm. The reason is that at the time this incident happened, this satellite had already lost contact.

The U.S. did detailed checks on Soviet antisatellite laser weapons. The U.S. itself also has this type of project. Not long before President Reagan put forward the development of antiballisitic missile systems, the U.S. Air Force drafted up a "Written Requirements Report" on antisatellite laser weapons. If this request is approved, antisatellite weapons will then become one new type of weaponry for the Air Force.

Besides antisatellite laser weapons, other methods for attacking satellites at the present time seem all still to have quite a few difficulties. Satellites move several hundred kilometers above the surface of the earth. They are targets that high power lasers can most easily destroy. This is because, when satellites move in outer space, they possess fixed orbits. The operations of a good number of satellites directly or indirectly depend on optical or infrared sensors, and it only requires lasers of low power to then be capable of blinding sensors. Even if satellites do not use optical or infrared sensors, due to accumulations of laser energy, it is also easy to cause damage. Today, speaking in military terms, (illegible) are important. In this area, the competition between the U.S. and the U.S.S.R is very intense. A good number of military personnel are racking their brains because of this. /227

12-1 Military Roles of Satellites

Since the Soviet Union launched the first man made earth satellite, within a period of a quarter of a century, a good number of nations all carried out nervous and intense contentions in this field. As a result, space was made into an extremely important part of military strategy. Spy planes which were used before, despite being capable of high altitude flight over enemy territory, were still susceptible to the threat of antiaircraft artillery. At the present time, spy satellites have already completely replaced spy planes, exerting an enormous effect militarily. Currently, the numbers of military satellites above the Earth is quite considerable. Military satellites have already become one part of military power (see Fig.12-1).

At the present time, the most numerous satellites in space are spy satellites using various types of methods to observe various types of incidents occurring at various places in the

world. Among 120 military satellites launched each year, approximately half are spy satellites. These satellites move in low earth orbit (150-400km from earth). At this altitude, they are capable of using very high resolutions to gather ground imagery (see Fig.12-2). These images are recorded by photographic negatives or by transformation into electronic signals transmitted to earth through communication satellite networks. Making use of this type of method, it is possible to confirm and resolve objects of 30 cm size. Intelligence agencies have already opted for the use of this type of technology in a wide spread way. For example, U.S intelligence personnel make use of satellite photographs taken of Soviet research installations, deducing that the Soviets are in the midst of carrying out development work on directed energy weapons. There are also some satellites used in oceanic observation and tracking the navy ships of other nations. There are also a number of satellites used in intercepting the wireless communications signals of other nations. In summary, spy satellites are capable of adopting several types of methods to collect intelligence, playing roles in a variety of areas.

There is one type of satellite that instantaneously concentrates attention on bombers and missiles in the process of being launched. Once signs of a nuclear attack appear, warnings are then immediately sent out. Because this type of warning

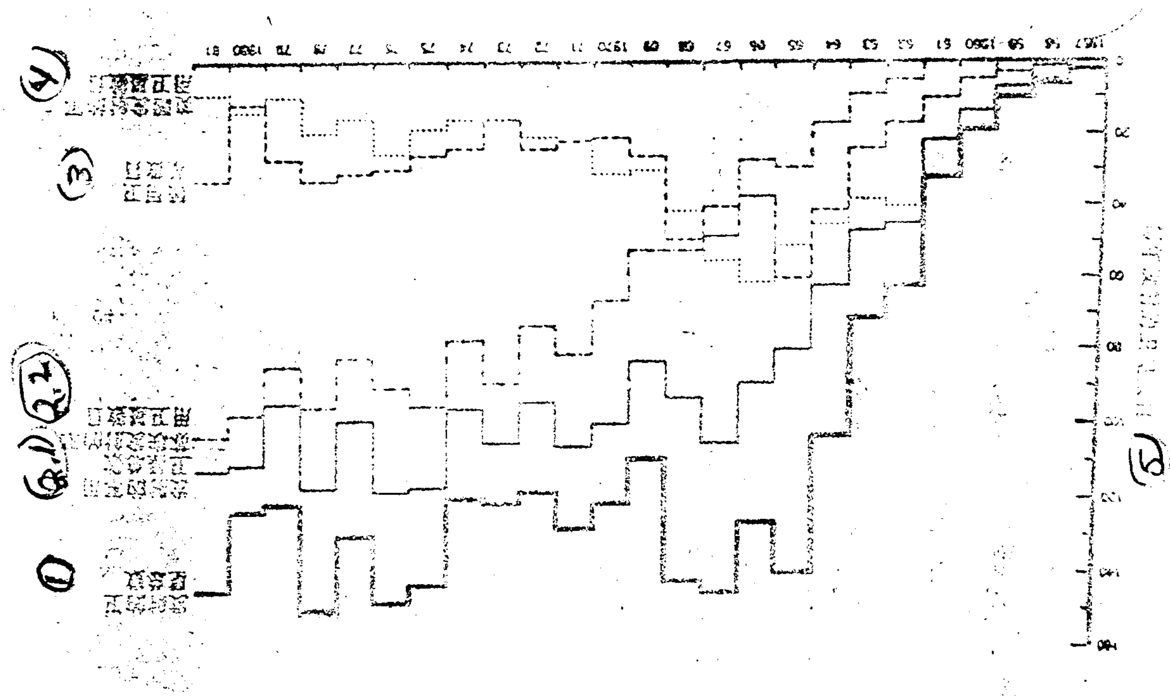

Fig.12-1 :Caption see next page

Fig.12-1 Numbers of Civilian and Military Satellites Launched in the Period 1957-1980. The numbers of satellites launched by the U.S. and the U.S.S.R are different. It clearly shows that the life of Soviet reconnaissance satellites is very short and not that there is a wide disparity in the number of military satellites between the two countries. (1) Total Number of Satellites Launched (2.1) Total Number of Military Satellites Launched (2.2) Total Number of Military Satellites Launched by the Soviet Union (3) Number of Civilian Satellites (4) Number of Military Satellites Launched by the U.S. (5) Total Number of Satellites Launched Each Year

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satellite is capable of forming a radar antenna network, Soviet and U.S. military strategists are all very dependent on them.

On the basis of satellite warnings, it is possible to order strategic nuclear bombers to take off. If it is discovered that the information is in error (that is, that it is certainly not a nuclear attack), bombers are capable of immediately returning. However, if the launches are nuclear missiles, then, there is a great possibility of starting a nuclear war.

Communications satellites are primarily civilian. However, that does not rule out military uses--for example, taking information obtained by spy satellites and sending it back to the country of origin after (illegible). Another example would be the U.S. and the Soviet Union having a number of military bases at various places in the world. Communications satellites can then act as a means for linking military bases separated by very great distances.

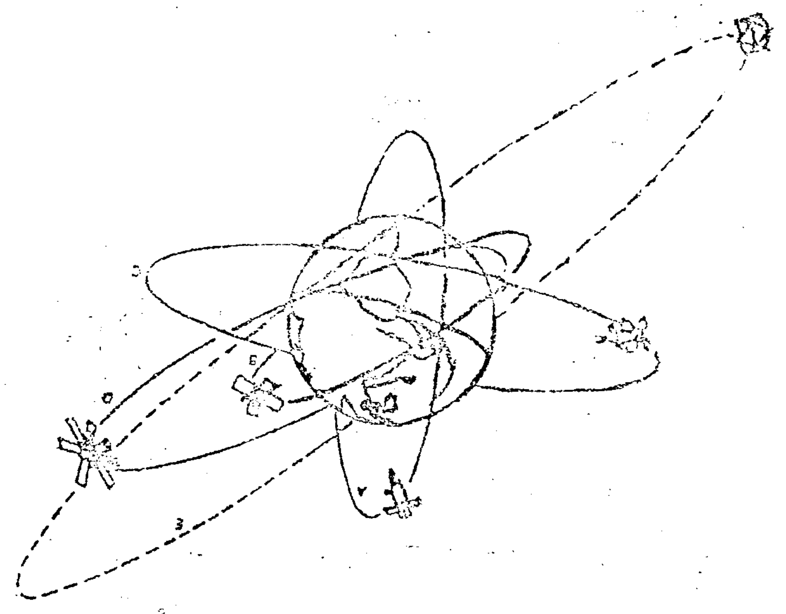

Fig.12-2 Different military satellites require taking up different orbital movements. Monitoring, navigation, and a number of weather satellites generally move in orbits A and B at heights of 180-1400km. The majority of warning satellites, communications satellites, and weather satellites all move in synchronous orbit C above the equator at 3600km. Some communications satellites and warning satellites move in elliptical orbit D. Most of the time, they are very far from earth and can reach 40000 kilometers. There are very short periods when they are very close to the earth, that is, 250-700 kilometers. The very distant E orbit is 110 thousand kilometers from earth. U.S. satellites checking on nuclear explosions travel in this orbit.

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Military satellites--besides monitoring, warnings, and communications--are also capable of engaging in indirect military work associated with military missions--for example, navigation satellites are capable of accurately determining the positions of airships, submarines, and other targets in order to supply navigation data. There are also a number of military satellites used in collecting data on the configuration of the earth's surface as well as gravity

fields in order to facilitate the accurate selection of flight routes by missiles. Military weather satellites, by contrast, are used in collecting meteorological data.

As far as military satellites with different operational characteristics are concerned, the heights of orbits that they occupy are also different. Reconnaissance satellites that depend on optical signals generally fly in orbits 130-400 kilometers above the earth's surface. Electronic monitoring satellites generally are at 500-650 kilometer altitudes. Navigation and communication satellites are generally in orbit around 600-1500 kilometers. Sometimes, they occupy synchronous orbits of approximately 36000 kilometers altitude and become synchronous satellites. Because the angular velocities of rotation of synchronous satellites around the earth and the angular velocities of the earth's rotation are the same, as a result, speaking in terms of observers on the earth's surface, synchronous satellites seem to be fixed in the heavens and not move. Synchronous satellites must be above the equator. Moreover, in order to make the emitted signals from two synchronous satellites not interfere with each other, a certain interval is required between synchronous satellites. As a result, the number of synchronous satellites permissible above the earth is limited. Internationally, agreements have already been reached with regard to synchronous satellite emissions. Various nations are capable of requesting their own synchronous satellite positions.

12-2 Satellite Weaknesses

People are well aware that satellites are very fragile. They can be very easily destroyed by attacks from laser weapons and other beam weapons. It is only in the last few years that the U.S. military began to consider problems existing with satellites in war.

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Speaking in terms of satellite movements, space several hundred kilometers above the surface of the earth is a very ideal vacuum environment. Objects moving here do not encounter air resistance. The influence of the earth's gravity can also be ignored. On the earth's surface, objects moving at high speed cannot be supported. In a vacuum environment, however, it is possible for them to move without limit. As a result, satellite structures are generally relatively light and maneuverable and cannot go through the strong vibrations during launch from the earth's surface. At the present time, the advanced technologies which have been opted for put a premium on satellite compactness to draw them in tight so as to make them capable of enduring the severe conditions during launch. Reaching high altitudes after launch, satellites then open out. Satellites moving in space are capable of meeting dangers. First of all, these come from collisions with stray meteorites, as well as cosmic dust, and residual material in space. What we are talking about here as residual material refers to a number of junk materials, wreckage, and so on, launched from the earth's surface into space. This space garbage moves at high speed's in upper earth orbits. Once they it collides with satellites, it is then capable of destroying them. Secondly, there are two radiation belts above the earth. The high energy particles within the belts

and other rays coming from outside will produce damage in electronic equipment on satellites. Functions will be destroyed. As a result, it is necessary to install radiation protection systems on satellites. Besides this, satellites in space receiving solar radiation on half their surface will produce relatively large temperature differentials. They must be able to endure the effects of these factors.

Besides the properties of space itself, strategic concepts associated with space also have extremely great influences on satellite design. Previously, people had no real concerns about satellite life, even to the point of there being no one inquiring into the problems of survivability of satellites during space warfare. Following along with the gradual militarization of space, the military only then really began to approach this question. After 1978, the U.S. government did a revision of space policies. President Reagan indicated that U.S. satellites must possess an offensive capability. In the not distant future, space satellites would be capable of no longer collapsing at the first blow.

12-3 Antisatellite Weapons

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Because the normal run of weapons have no chance against satellites in orbit several hundred kilometers above the earth, one, therefore, simply needed to send satellites aloft and there was then no need to worry that there would be any weapon capable of destroying them. However, following along with daily enlargements in the role of military satellites, numbers

constantly increase. Antisatellite weapons also follow along with this and appear.

Early in 1963, the Soviet Union began the development of antisatellite weapons. The antisatellite weapon is an "assassin" satellite. On this satellite are loaded conventional explosives.

They destroy target satellites through approaching targets and producing explosions. However, this type of method is only capable of dealing with satellites moving in relatively low earth orbits. With respect to satellites in relatively high orbits of several hundred kilometers, it is necessary to opt for the use of other weapons. On the basis of analyses of the U.S. side, the Soviet Union is in the midst of developing this type of weapon (refer to Fig.12-3).

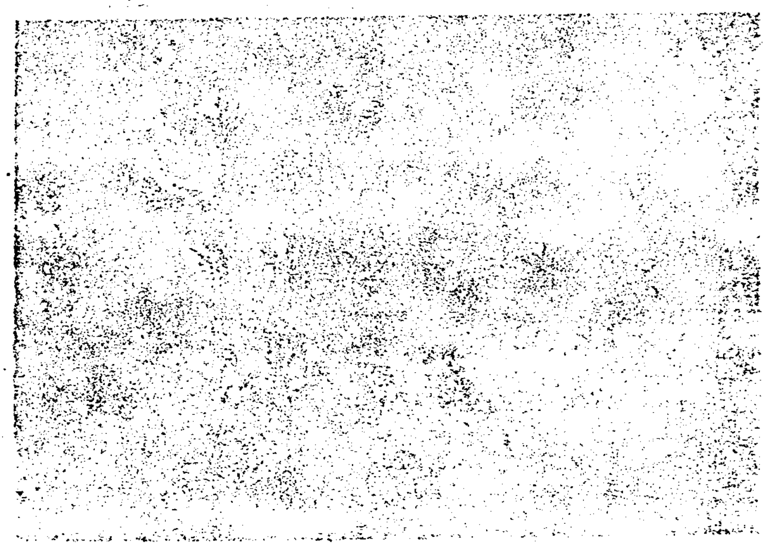

Fig.12-3 Soviet Antisatellite Weapon Approaching Target Satellite in Orbit and Exploding, Releasing Large Numbers of Small Balls to Destroy Satellite (Schematic).

The methods adopted by Americans building antisatellite weapons and those of the Soviets are completely different. The U.S. antisatellite weapon is a two stage "micro homing aircraft" launched from the F-15 interceptor in order to attack targets. The U.S. Air Force hopes that this type of hugely expensive system will be able to go into use at the end of the 1980's (see Fig.12-4)

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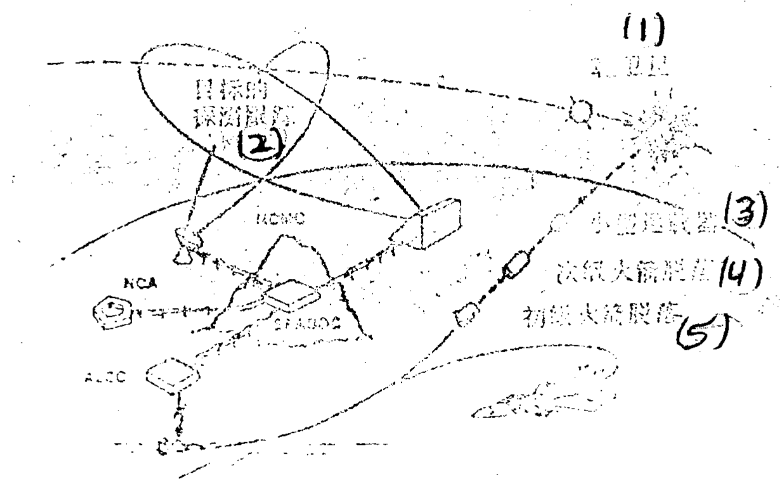

Fig.12-4 In this U.S. space launched antisatellite system, target satellites are tracked from the ground. The data is processed by NORAD Headquarters in Cheyenne Mountain and space defense control centers. Orders from national command authority are first transmitted to space launch control centers and then transmitted to F-15 fighters carrying missiles. After these fighters receive the commands, they immediately take off. In conjunction with this, they launch missiles which automatically home on targets, destroying target satellites. (1) Target Satellite (2) Target Detection and Tracking (3) Small Carrier Craft (4) Second Stage Rocket Drops Off (5) First Stage Rocket Drops Off

12-4 Laser Antisatellite Weapons

There are four possible methods for actually countering satellites, that is, there are four types of antisatellite weapons which offer options. These are missiles, ground based lasers, airborne lasers, and space based lasers. The last three types are all laser weapons (refer to Fig.12-5). Countering satellites is the most practical military use of laser weapons. A good number of satellites are easily destroyed after laser attacks.

The level of destruction satellites sustain from lasers depends on a number of factors--for example, laser power, weapon focusing characteristics, as well as satellite altitude, and so on. Laser beams shined on satellites will form a facula point. The higher power densities are, the more severe the destruction will be on the satellite. The problem lies in the fact that,

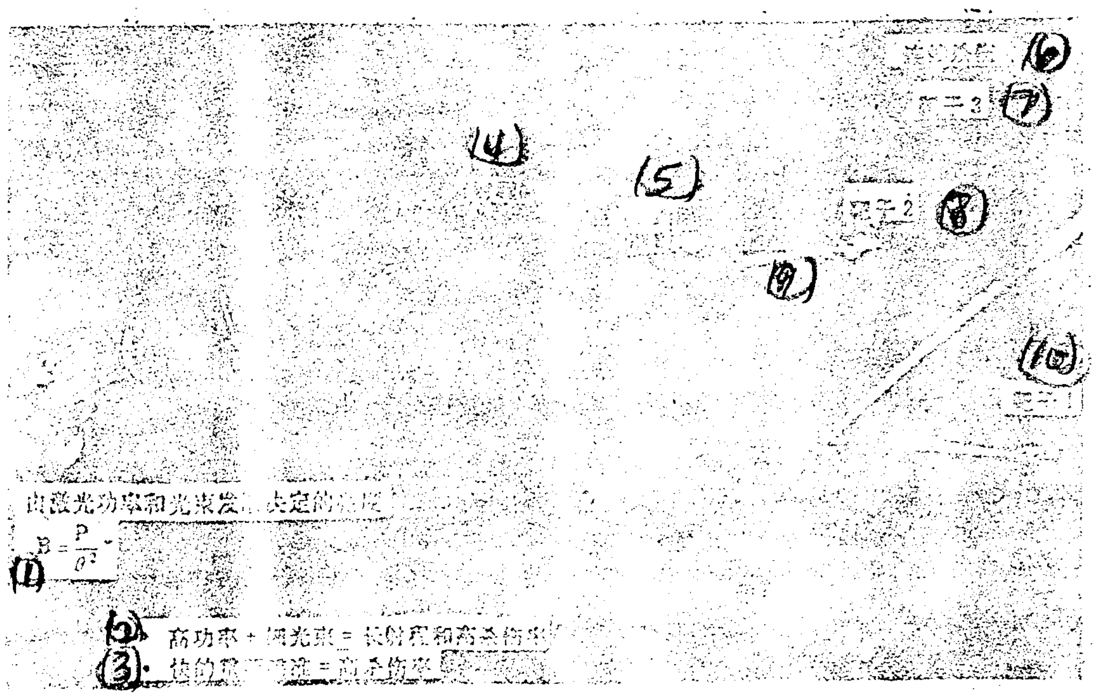

Fig.12-5 Directed energy weapon efficiencies depend on degrees of brightness and reaiming times. High brightness and short reaiming times (illegible) produce very high efficiencies. Brightness or energy associated with each unit solid angle is determined by the energies of rays themselves and beam divergence angles. The higher energies are, the higher brightness then are. The smaller ray divergence angles are, the larger brightness then are. Because divergence angles and ray wave lengths as well as their diameters form a fixed proportion, therefore, short wave lengths added to large diameter reflector mirrors mean high brightness. (1) Brightness is determined by laser power and light beam divergence. (2) High Power + Fine Light Beams = Long Range and High Kill and Damage Rates. (3) Fast Reaiming = High Kill and Damage Rates. (4) Range (5) Reaiming Time (6) Sustained Kill or Damage (7) Target 3 (8) Target 2 (9) Illegible (10) Target 1

when satellite orbits are very high, facula points are very large. Power densities are very, very greatly reduced. For example, if a laser irradiates a reconnaissance satellite at 360 kilometers, the facula bright spot diameter is 1 meter. When laser beams irradiate synchronous satellites at altitudes of 36000 kilometers, facula diameters then become 100 meters. Power densities are reduced to one ten thousandth of the originals./235

Due to satellite altitudes being very high, it is necessary for the beams of satellite weapons, as a result, to have relatively good focusing properties. To this end, it is necessary to use very large focusing mirrors.

A good number of satellites require the use of sensors to collect information--for example, the eyes of spy satellites are simply a sensor. This type of sensor can be an optical sensor. It can also be an infrared sensor. However, no matter which type it is, it is easily attacked and destroyed by laser light in all cases. A number of nonreconnaissance satellites--such as communications satellites--also have sensors. However, these sensors are not used to collect intelligence, but are used to fix positions, making satellite transmission antennas point toward the earth. If antenna directions are toward space and not pointed toward receiving antennas on the earth, this satellite then also losses its function. Although the sensors of this type of satellite are not as fragile as the (illegible) eyes of spy satellites, they are, however, easily destroyed by laser attacks.

Besides this, the majority of all satellites have a solar energy cell set to supply energy to the satellite. Solar energy cell panels are also similar to

(illegible) eyes of spy satellites, they are, however, easily destroyed by laser attacks.

Besides this, the majority of all satellites have a solar energy cell set to supply energy to the satellite. Solar energy cell panels are also similar to an optical sensor. If one takes this "sensor" and destroys it, satellites then have no way to operate. Summarizing the above, sensors on satellites are a fatal weak point of satellites. Once one takes satellite sensors and destroys them, this then means that the whole satellite is incapable of functioning. Because of the ease of destroying sensors with lasers, using laser satellites to attack satellites is, therefore, quite successful. For example, it is only necessary to heat infrared sensors, and it is then possible to destroy their operation. Infrared radiation is emitted from objects at room temperature. In order to avoid interference coming along with radiation from probes themselves, infrared detectors need to operate at low temperatures. Using lasers to heat detectors, radiation from detectors themselves is then able to cause annihilation of infrared signals, creating sensor malfunction.

Laser weapon powers are different, and degrees of damage to sensors are different in the same way. Roughly speaking, damage is of the several types below:

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(I) Using powers which are much stronger than conventional sensor observation powers to irradiate sensors will cause temporary malfunctions of sensors. This is the same as a search light at night shining on a person's face, making all objects in the field of vision be annihilated by

the strong light and creating a similar effect to making the person temporarily blind.

(II) As far as using very strong power irradiation of sensors is concerned, signals received by sensors will then be very strong, making electronic circuitry show overloading. Operating performance will drop, even to the point of not being able to operate.

(III) With regard to the irradiation of sensors by very strong powers for long periods, this produces heat damage, that is, sensors are heated, making impurities within electronic components diffuse. Operating characteristics of electronic components change, making sensor performance turn bad, even to the point of a complete inability to function.

(IV) Physical damage is produced in sensors, optical systems, as well as electronic systems. (Illegible).

Even if satellites opt for the use of countermeasures, making sensors capable of avoiding destruction, very strong laser irradiation on satellites will, however, still produce intolerable thermal effects. As far as satellites placed in outer space are concerned, after being heated, it is only possible to release heat through radiation. There is no way for it to be done through convection. Amounts of heat will be released through radiation much more slowly than through convection. As a result, under laser irradiation, satellite temperatures will rapidly go up. Thus, operation of electronic systems is destroyed, even to the point of destroying the operations of the entire satellite.

12-5 Ground Based Antisatellite Laser Weapons

Antisatellite laser weapons are basically of three types. They correspond respectively to laser weapons placed on the ground, in the air, and in space.

Ground based laser weapons are generally placed on the tops of high mountains. In this way, they are somewhat closer to "heaven". Their greatest advantage lies in their manufacture, maintenance, and movement all being relatively simple. At the present time, the volumes of high energy lasers are still enormous. If one wishes to mount them on aircraft or launch them into space, it is still quite difficult. Secondly, taking lasers and mounting them on the ground, it is not only easy to replace electrical power supplies or fuel, moreover, maintenance is extremely convenient. At the present time, the reliability of high energy lasers and the reliability required by military systems are still very far from each other. Moreover, utilization and maintenance of this type of weapon requires small detachments composed of scientists who have gone through /237 specialized training in order to assume this mission.

Another advantage of ground based lasers is that problems of vibration and interference associated with airborne and space based laser weapons do not exist. The reason is that tiny movement instabilities associated with aircraft or satellites will all severely influence the tracking and directing of laser weapons. Relatively

speaking, directing and tracking from the ground are both comparatively simpler and more convenient.

Satellites under laser weapon attack seem unusually fragile.

As a result, power densities needed to attack satellites can be much smaller than those for dealing with other targets. Moreover, beam focusing requirements are much lower. It is also possible to ignore tiny atmospheric influences. However, under bad weather conditions, interference effecting ground based laser weapons is very severe.

People always believe that satellites are placed at very high altitudes above the earth. However, this is certainly not the case. For example, satellite altitudes of 400 kilometers above the ground are only 7% of the earth's diameter. Seen from space, satellites are almost stuck to the earth's surface. The altitudes resemble the thicknesses of the skin of a grape. Satellites at altitudes of 400 kilometers move distances of 2300 kilometers horizontally. This is only 2% of the circumference of the orbit. Moreover, the time utilized is very short. This then limits the window appropriate to attacks by ground based lasers. At the same time, when the angle between the laser beam attacking the satellite and the horizontal is smaller than 45°, it must go through very thick atmosphere. In the same way as sunlight at sunset, atmospheric interference is very severe. In this way, the effectiveness of ground based lasers is then limited to a very small range, that is, most satellite orbits are not within laser firing ranges. However, if the number of ground based laser sites is very large, satellites will still be threatened.

As far as satellites moving in very high orbits are concerned, the time periods during which they stay within the attack spread angles of ground based laser weapons are relatively long. The places where it is possible to fire toward satellites are very numerous. If one is dealing with synchronous satellites, seen from the ground, they appear fixed above the earth. Aiming at them and initiating attacks is relatively easy.

However, with regard to satellites in high orbit, focusing and beam transmission is a severe problem.

In order to make the attack ranges of ground based antisatellite laser weapons not suffer from limitations, it is possible to use orbiting reflector mirrors in order to /238 redetermine direction. That is, using a number of reflecting mirrors, one connecting to another, they take turns entering the areas above ground based laser sites to reflect laser beams. Laser beams are made to focus through remote control reflector mirrors. At the present time, there still exist such problems as the atmosphere blocking beams and how to launch the huge orbiting reflector mirrors.

12-6 Airborne Lasers

As the name implies, airborne lasers are nothing else than laser weapons placed on aircraft. Modern military aircraft have already developed to quite a perfected extent. It is possible to fly at the top of the atmosphere. Moreover, they are capable of coping with various types of bad weather. Even commercial jet passenger planes generally all also fly at altitudes 10 kilometers off the ground. This altitude is equivalent to 3/4 of the atmosphere. At altitudes of 15 kilometers, the thickness of atmosphere

between aircraft and outer space only accounts for 1/8 the thickness of the atmosphere. At this altitude laser beams are sufficient to break free from problems which come with propagation in the atmosphere.

Taking lasers and mounting them in aircraft, it is possible to overcome a number of the difficulties existing with ground based lasers. Interference produced in beams by the atmosphere will be very, very greatly reduced. At the same time, the attack range is also expanded. Satellite orbits are fixed. Aircraft can carry lasers to appropriate positions. After waiting for satellites to fly by, they then carry out attacks. Although aircraft speeds are much slower than satellites, aircraft are capable, however, of flying in the same direction as satellites. In this way, it is then possible to extend attack times (see Fig.11-5).

Airborne lasers also encounter a number of new problems. First of all, taking lasers and putting them in aircraft is certainly not an easy matter. Their enormous volumes are one big problem. Besides this, optical systems installed in aircraft must be able to handle the vibration of the aircraft in their direction determination and tracking systems. This then requires optical system errors being very small. As a result, research on antivibration technologies is clearly very important.

Secondly, direction determination and tracking systems must be capable of correctly compensating for the various types of aircraft movements, being capable of rapidly feeding back information acquired on targets. Tiny changes in aircraft direction as well as aircraft vibrations are all capable of making beam directions give rise to very large deviations. It is necessary to take beam directions and fix

them right through on moving targets.

Besides this, taking lasers and loading them on aircraft, it is certainly not possible to perfectly overcome the influences of the atmosphere on beam propagation. In aircraft flight environments, there is still a small amount of air. This will carry with it definite effects on beam propagation. As far as high speed aircraft flight is concerned, it makes the atmosphere produce vibrations. Laser behavior in this type of complex air flow environment is also very complicated. There are a good number of technical difficulties which still exist here.

12-7 Antisatellite Laser Satellites

It is necessary to thoroughly resolve transmission problems with antisatellite laser weapons in the atmosphere. The only method is to take laser weapons and mount them on satellites. Satellites will be much more stable than aircraft. There are no interference problems from air currents and flight vibrations. There is no need for the antivibration optical components used on airborne lasers. Satellite orbits are known to every one. As a result, the problems of directing beams are very, very greatly reduced. If target satellite orbits are also known, directing and tracking problems are then very simple. Despite the fact that the astronavigation technology of various nations has already made very great progress, with regard to antisatellite laser satellites, however, there are still a number of difficulties. According to reports, in 1987, the Soviet Union already built one type of large carrier rocket with launch weights capable of reaching 2000 tons. However, taking a laser weapons system and the necessary fuel and launching them at one time into space is a huge project.

There are still very numerous difficulties existing with this.

After taking laser weapons and launching them into orbit, it is necessary to maintain the reliability of antisatellite laser satellites. Maintenance is quite troublesome. There are still a good number of technical difficulties in this area. Besides this, the development of reliable remote control communications systems is also very important speaking in terms of antisatellite laser satellites.

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Chapter XIII BATTLEFIELD BEAM WEAPONS

The Pentagon is not only looking very closely into beam weapon development. At the same time, it is also in the midst of exploring taking them and turning them into a new generation of tactical weapons used on the ground, the sea, and in the air. The U.S. Defense Department took out 2 billion U.S. dollars from laser weapon development expenditures and used it in this project.

In late 1981, the former chief of the Defense Advanced Research Planning Agency, Robert Kupo said: "Speaking in terms of an exploratory project, 2 billion U.S. dollars is a "huge figure". Laser weapons possess tremendous potential. Speaking in terms of ourselves, this is an unusually good opportunity. We will take high energy laser weapons systems and use them on the battlefield. They will definitely be weapons systems welcomed by military units."

H.G Wells and other similar science fiction novelists, in their works, have produced some cursory readings on tactical beam weapons. However, in the time when Wells was writing, strategic weapons possessing huge destructive power had not yet come out. Ten years before the Wright brothers made the first powered flight, "War of the Worlds" had already been published. In that era, physicists still took atoms to be eternally invariable little balls. At that time, Wells and other science fiction novelists all possessed a different level of concern. They wrote science fiction as a living. They needed to tell a story. What was involved in those stories was a war between humans and people from other worlds. What the people in the stories used were, for example, ray guns and airship type weapons. Besides death stars like the one in "Star Wars", science fiction writers, in their works, basically have not brought up strategic weapons.

Combat cases from the Second World War clearly show that technology on the battlefield is unusually important. Without doubt, directed energy weapons on the battlefield have a number of advantages. The most important is high beam speeds.

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Light propagates at a speed of 300 thousand kilometers/second. This is 40 thousand times the speeds of the fastest current rockets. With regard to fast targets moving more than a few kilometers, in actuality, it is not necessary to take a lead. Light, in 1/6 millionths of a second, is capable of flying 50 meters. However, aircraft flying at twice the speed of sound, within the same period, are only capable of flying 0.1 mm.

Although laser weapons hitting targets do not necessarily require a lead, lasers require, however, tracking targets 1 second or irradiating the surface of targets for adequate periods in order to produce effective mechanical destruction.

Charged particle or neutral particle beams in a vacuum are also capable of approaching movement at the speed of light. However, in the atmosphere, burning a path through, will make charged particle speeds drop to approximately 1000 kilometers/second. Although this is the case, it is still 1000 times the speed of the fastest jet plane. Even if it is necessary to take a lead, it will be extremely small. What can be expected is that, when particle beam weapons hit targets, firing only once will be sufficient to destroy targets. As a result, beams need not stop over very long periods on targets.

Fast speeds are certainly not beam weapons' only advantage. Highly directed beams are capable of directly hitting enemy targets. However, they will not also produce damage by mistake on friendly equipment and personnel in the vicinity. This point is very useful on the battlefield. For example, when aircraft from the two sides engage in the air, through rotating reflector mirrors, it is possible to rapidly take laser beams from one target in the sky and move it to a different target (changing particle beam direction, by contrast, is very difficult). Due to lasers not needing to use missiles for delivery, they can transmit themselves onto target objects. At the same time, they also do not need fuse systems to carry out detonations. As a result, when they destroy targets, beam weapons have much stronger capabilities to resist electronic interference than conventional tactical missiles.

If beam weapons are used on the battlefield, people naturally hope that the types of weapons in question have tightly concentrated firepower. Although laser or particle beam generating systems have huge volumes, they are capable, however, of carrying with them large amounts of operating media or fuel. As a result, it is possible to fire multiple times. At the same time, it is also possible to continuously replace operating media. One particle beam generator is capable of firing several times in one second. Lasers that want to kill or damage a target require 1-2 second durations. This is much shorter than the durations /242
conventional tactical missiles use to kill or damage targets. On the fast changing high technology battlefield, the quick initiation capabilities of lasers and their reaiming capabilities possess very great advantages. On this type of battlefield, fast flying weapons flash through the air. Soldiers, besides dodging into shelters and letting flying weapons pass them by, are almost in a state of inertia.

The Pentagon hopes that beam weapons will not cost too much money. The price for one set of battlefield laser systems is 5 million to 10 million U.S. dollars. Moreover, the price of particle beam systems is perhaps even higher. Military estimates clearly show that, at least speaking in terms of lasers, firing once will be much cheaper than firing one tactical missile. This is because, the more complicated short range missiles are, the higher their prices are. Ground to air "Stinger" missiles weigh 10 kg. They have a range of 5 kilometers. Each missile costs 20000 U.S. dollars. Moreover, long range surface to air "Patriot" missiles weigh 1000 kg. Each missile will make the Pentagon spend 300000 to 500000 U.S. dollars. In comparison, using deuterium fluoride lasers, firing once will be much cheaper. The cost of the fuel used, in all cases, is 1000 - 2000 U.S.

dollars. This is almost the equivalent of the expenses associated with firing one missile. With regard to carbon dioxide lasers, firing once has a fuel consumption which is only a few hundred U.S. dollars.

Pentagon efforts in the area of tactical beam weapons are primarily concentrated on lasers. The Navy was in the midst of developing the use of charged particle beams in order to defend against cruise missile attacks on warships. This is nothing else than the project called "Enjoy the Inheritance at Leisure" project (referring to applications). Later this project returned to the Defense Advanced Research Planning Agency for tests on advanced experimental accelerators. Tactical microwave beam weapons, at the present time, still remain on the table. They must await a deeper understanding of the effects of microwaves. Only after that will it be possible to draw conclusions. Due to the scale of laser research projects being relatively large, the work is relatively mature. Below, we will use a certain scope to discuss it.

13-1 The Targets [of Beam Weapons]

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In theory, beam weapons can carry out any kind of mission, no matter if it is in the air, on the sea, or on the ground. As a defense official said informally, "Lasers can hit any kind of moving or flying target, even though they can't pierce four-inch-thick tank armor." These words are very meaningful, because they are based on this fact: to penetrate armor, a weapon must have sufficient momentum, but, in a practical sense, lasers have no momentum. However, projectile weapons, such as missiles and cannon shells, can penetrate armor because they have momentum. Thus, they can be used on the future beam weapon battlefield to attack armored targets. Beam weapons can be used to attack the fatal weaknesses of armored weapons, such as sensors.

American military heads are eager to find a kind of beam weapon that can be used to destroy battlefield targets other than weapons with thick armor plating. Each armed service is carrying out its own research plan. This shows that each has different needs. Different kinds of lasers are necessary for attacking different kinds of targets, and different armed services need to operate lasers in different environments according to their own demands. For example, the environment in an airplane is very different from that on a ship, and both these environments are dissimilar to the environment in a tank.

The three different kinds of research projects reflect the traditional competition between the services. Critics say that
(continued on page 355)

carrying out three sets of research projects in the early phase of the development of technologies is an extremely large waste of money. One famous person enthusiastic about lasers--Senator Haoweier Haifulin--complained that taking Pentagon laser weapon projects and dividing them up among the various services and the Defense Advanced Research Planning Agency will lead to waste of financial resources in small amounts of technology testing. Moreover, these are not used in overall research where expenditures are needed more. He suggests that a powerful central agency should be set up in order to coordinate laser weapon research projects with the National Laser Research Committee coordinating all government funded civilian and military laser research. Setting up this type of high level, separate coordinating structure is an important objective for early 1982. In the final analysis, directed energy weapon development projects are taken charge of by the Deputy Secretary of Defense for Research and Engineering Projects. This position was originally the responsibility of Major General Lanbosen. Later, it was handed over to Brigadier General Lanjinna.

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Although there were very great differences in laser weapon requirements because the missions that needed to be completed were different, speaking in terms of tactical laser weapons, however, they had a number of common points. It is necessary to understand this one point. It is best to take the special characteristics of targets themselves and make them the starting point for research. There are three main types of potential targets on the battlefield: soldiers, sensors, and other hardware. Below, we will carry out discussions of them respectively.

13-2 Lasers Aimed at Soldiers

The real method of operation of beam weapons killing and injuring soldiers is totally different from the immediately fatal method of operation in science fiction works and the almost instantaneous incineration described in Wells' "War of the Worlds". Theoretically speaking, using high power microwave beams, it is possible to kill and wound soldiers. However, there is no way to make use of the huge antennas which it requires on the battlefield. If charged particle beams are capable of penetrating air, it is also possible to kill and wound soldiers. However, this is just like the adage about "using an antiaircraft gun to shoot a mosquito"--a large use of material to little effect. Finely focused laser beams are capable of burning skin. However, unless the ranges are very close, it is not otherwise possible to cause death. The human body has one place which can be harmed by lasers with unusual ease. This is nothing else than the eyes (refer to Fig.'s 13-1 and 13-2). Sensor sensitivities change along with wave length. This phenomenon also applies to the eyes. The eyes are most sensitive to visible light. Eyes directly facing the sun for long periods of time or only a few thousandths of a watt of visible light entering the eyes and it is possible in all cases to give rise to permanent retinal damage. The retina is located on a very thin membrane at the back of the eye ball. It is capable of sensing light stimulation. In conjunction with this, the images are taken and sent to the brain. Due to the fact that the lenses of eyes are capable of focusing visible light and near infrared, as a result, when they highly concentrate the power of light, it is then possible to cause burn damage to the retina. High power lasers are capable of causing harm within even shorter periods of time. Moreover, short light pulses of certain strengths are even more dangerous. The result is not to make the eyes turn blind. It is simply to give rise to partial blockage of vision. This type of

harm can be permanent. It can also be temporary. This is determined by the power of the laser.

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For a long time, the U.S. military has paid very great attention to the effects of laser beams on eyes. Their initial interest certainly did not come from laser weapons. It came, by contrast, from using low power visible light or infrared lasers to carry out range finding on targets, and, in conjunction with that, guiding smart bombs in tracking targets. However, this type of short pulse is very weak. It is basically just not capable of harming skin. However, it is still capable of producing permanent damage to eyes.

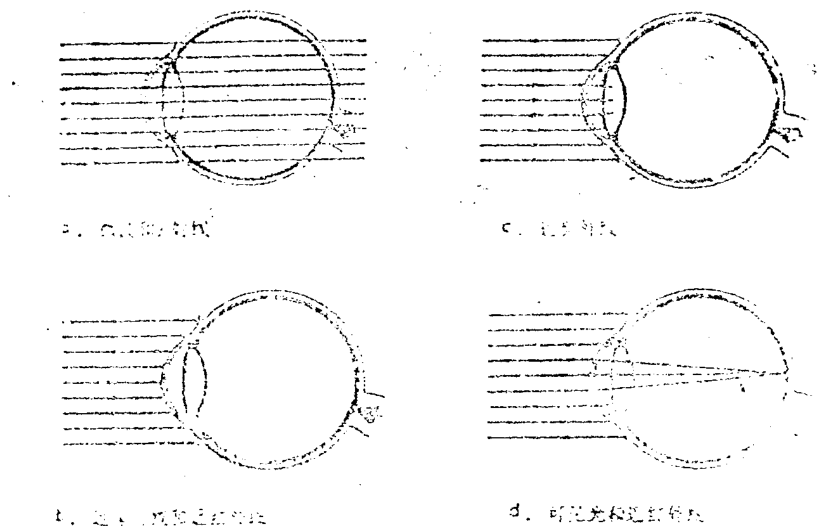

Fig.13-1 Mutual Effects between Electromagnetic Radiation of Various Wave Lengths and Eyes. Microwaves, γ rays, X rays, and a number of other forms of radiation are capable of directly penetrating eyes. They do not have (illegible) mutual effects on eyes. In practical applications, near infrared radiation has very good capabilities for penetrating the atmosphere. However, they are still capable of being absorbed by the lenses of people's eye balls. Infrared radiation with wave lengths of a few microns can be absorbed by the outer surface layers of eyes, corneas, and so on. Strong laser beams can give rise to (illegible) eye damage. Adequately strong visible light or infrared laser beams are capable of being focused on the retina at the back of the eye ball. In conjunction with this, people's vision is destroyed. a. Microwaves and Gamma Rays b. Far Ultra Violet and Far Infrared c. Near Ultra Violet d. Visible Light and Near Infrared

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In order to satisfy war requirements, it is sometimes necessary during combat to fire laser beams toward enemy soldiers. However, if there are also friendly forces participating in military maneuvers or training, that problem then comes up. This type of training is extremely important to combat readiness. It is sometimes necessary to make use of real weapons. In the U.S., due to concerns that lasers are capable of creating damage in soldiers' eyes, research has been stimulated on new types of laser materials. This type of material emits wave lengths which are safe for eyes. They cannot penetrate eye balls. In Europe, this problem is more severe. The reason is that, there, inhabitants are very close to military training bases. They can be harmed by scattered laser pulses.

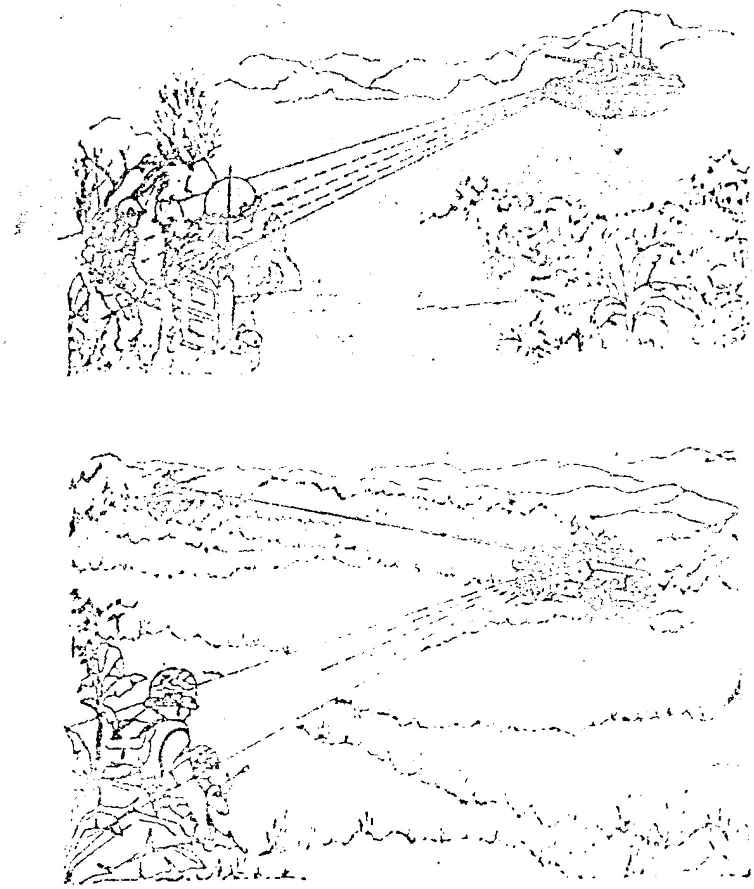

Fig.13-2 Light pulses emitted from laser range finders are capable of damaging soldiers' eyes. No matter whether it is direct exposure to laser beams (top Fig.) or indirect exposure to light reflected back from other surfaces which resemble mirrors (for example, rear view mirrors of trucks) (bottom Fig.), in all cases, they are capable of harming people's eyes. Even if it is not this type of special use laser system, a number of coincidental factors are also capable of giving rise to eye damage.

When making use of laser range finders and direction finding instruments, it is possible that they will give rise to eye damage. Using high power lasers, it is possible to make enemy soldiers' eyes temporarily or permanently blind. This depends on the power and wave length of the laser. At the present time at least, it is still not widely known whether or not the U.S. has done work in this area. In October 1981, in a book called "Soviet Military Power" published by Pentagon officials, great interest was shown in Soviet use of laser weapons to harm the human body.

The types of physiological damage given rise to by lasers depend on laser power, pulse duration periods, and wave lengths. Wave length is particularly important in determining types of eye damage. Wave lengths 0.4 - 1.4 microns, that is, light waves placed in the visible or near infrared areas, are capable of penetrating eyes. The reason is that lenses will focus this type of light on retinas. A short, strong pulse is capable of producing damage to retinas, giving rise to bleeding, and, in conjunction with that, creating permanent blind spots. Long term exposure to low power lasers will also create damage on retinas. If eyes are harmed, that is very serious. It can create long term sight impediments. At the present time, it is still not clear how large an influence eye damage is to the combat power of enemy soldiers. Perhaps this will make them angry, fighting with additional courage and ferocity.

Light waves whose wave lengths are somewhat short or somewhat long are only capable of slightly penetrating eye balls.

Light rays with shorter or longer wave lengths, by contrast, cannot. Strong ultra violet light is capable of carrying with it a series of problems. These include causing temporary blindness, and, in conjunction with that, causing damage to corneas. This is very similar to sunburns caused by ultra violet radiation. Corneal damage is related to total amounts of exposure. There is no relationship to the speed or slowness of exposure. The critical value is very low--approximately 0.005 Joules/cm2 . This is equivalent to 0.005 watts/cm2 each second or close to 0.0001 watts/cm^2 each minute. Generating sunburn requires a few hours. Speaking in terms of its acting as a weapon, this long a period to act is nor appropriate.

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As far as short, strong light pulses coming from infrared lasers are concerned, the sustainment periods are from a few ten millionths of a second to a billionth of a second. With regard to eyes, this is unusually dangerous. They use a type of mechanism which is still not completely clear to make corneas undergo damage. The mechanism is not the same as with ultra violet light. Tests clearly show that, when the power densities are 0.005-0.01 Joules/cm2 , it is then possible to create eye damage.

Long term exposure to lasers associated with infrared wave band light produced by deuterium fluoride lasers or carbon dioxide lasers is also capable of giving rise to corneal damage. Corneas can almost absorb all the light in this wave band. The method described above of making eyes blind also supplied a type of protective method turned the other way around. Intense infrared light is capable of damaging corneas, and, in conjunction with that, giving rise to pain. If one is thinking of doing damage to corneas, one must then--before the eyelids shut--use power densities

exceeding 10 watts/cm^2 to release continuous laser power densities of 0.5 - 10 Joules/cm^2 and only then will it work. Once the eyelids shut, strong skin absorption will block long infrared light entering the eyes. Soldiers can also opt for the use of movement methods to cause eyes to avoid laser light. This only requires turning the face or using the hands to block the face or crawling on the ground, and that will do it.

Strong infrared light capable of giving rise to cornea damage is also capable of burning exposed skin because skin is capable of intensely absorbing infrared radiation. Indeed, with regard to a certain waveband of infrared light, skin is more sensitive than the eyes. It has been reported that, taking people and exposing them to strong infrared light given rise to by explosions, this type of infrared light will cause damage to skin, however, externally exposed eyes are still safe and sound. Powers which are capable of giving rise to skin burns are very high. However, they are still within the power ranges associated with laser weapons. If one wishes to create this type of injury, it is necessary to take continuous laser beams with power densities of 10 watts/cm^2 (strength--100000 watts) and concentrate them within a spot of a size with a diameter of 1 meter. On the battlefield, this can be done. Skin wave length absorption percentages for carbon dioxide laser light and chemical laser light are about the same. However, with regard to visible light or ultra violet area light waves, absorptions are very small (in the visible or near infrared wave bands, black skin and white skin show very large differences in light absorption; in longer infrared wave bands, there are then no obvious differences in light absorption).

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As far as intense flash is concerned, it is possible to produce a type of phenomenon called "flash blindness". People who have seen a flash bulb go off have all had a similar sensation. Residual image coming from the flash will temporarily remain in the eyes. After a period of time has passed, only then is it possible for it to disappear. How long this effect persists is determined by the strength of the flash as well as the total amount of light irradiation on the subject. At sites far from nuclear explosions, simulating this effect clearly shows that, if the weather is fair outside, the sustainment for "flash blinding" a person is approximately 10 seconds. However, the "flash blindness" period for pilots flying at night is more or less 100 seconds. Lasers can be used in order to initiate this type of "flash blindness" effect.

It is only necessary to adopt a number of simple measures, and it is then possible to effectively protect soldiers, making them avoid harm from this type of effect. Even if it is ordinary clothing, it is also capable of supplying a certain protection, and aluminum film type clothing is then better. At the present time, one type of eye protective glasses capable of absorbing a definite wave length have already been developed. In the laboratory, they are capable of protecting the eyes of operating personnel, avoiding damage from scattered laser light. Just as will be talked about later, military experts studying "flash blindness" have already discovered a type of optical material capable of turning black within a few thousandths of a second to a few millionths of a second. Of course, speaking in terms of certain effects, this reaction time is still not fast enough. However, compared to reflex processes under eye blink conditions, it will then be much faster.

Nature generously supplies certain simple protection against infrared and ultra violet light. Ordinary lime glass is capable of intensely absorbing ultra violet light with wave lengths shorter than 0.3 microns. Boron silicate glass is capable of intensely absorbing infrared light with wave lengths longer than 4 microns. It is also capable of absorbing the entirety of carbon dioxide laser light with wave lengths of 10 microns as well as 80% of deuterium fluoride chemical laser light with wave lengths of 3.8 microns. As a result, simple eyeglasses and the observation windows of tanks and aircraft cockpits are all capable of producing laser light protective effects against multiple types of wave lengths unless laser powers are high enough to break the glass.

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At the present time, near infrared and visible light lasers still have difficulty in reaching powers as high as those associated with infrared wave length lasers. However, they are still very difficult to protect against. The operating wave bands are zones that eyes are particularly sensitive to. Almost all optical materials transmit visible and near infrared laser light in the same way that glass transmits visible light. There are some optical instruments that not only are not capable of protecting soldiers, but, conversely, will create harm. For example, a pair of binoculars is capable of taking laser pulses scattered on the binoculars and collecting them, creating damage in the eyes of the soldier staring through them with fixed attention. Special protective eye lenses are capable of blocking certain specially selected wave lengths of laser light. However, if one wants to put them into practical use, it is then necessary, first of all, to know the laser light wave length. Making use of this type of eyeglasses always influences vision. Experimental researchers discovered that wearing them is very uncomfortable. At the present time, most range finders and

aiming devices all operate in the near infrared range of 1.06 microns. Researchers at the moment are just in the midst of studying models of lasers whose wave lengths are not in this range. Among them, there are a number which are potentially harmful to eyes. There are some others, by contrast, which are safe because they are not able to enter into eye balls.

In commonly seen U.S. military publications, there is not one which is related to taking laser range finders and position fixing instruments and using them to act as weapons. At least, military publications are this way. However, nonmilitary publications still say that, during times when combat enters a white heat, soldiers will use whatever they grab onto. This includes the laser light emitted from range finders and aiming devices. If it is very close, this type of beam is also capable of giving rise to eye damage. However, in the end, how this type of laser has a military effect of making enemy soldiers lose combat power is still, at the present time, unclear.

In reality, there are two important factors limiting the effects of laser weapons on soldiers. They both come from this type of fact, that is, lasers propagate in a straight line mode. Although, speaking in terms of a number of laser weapons, this is an advantage, when dealing with soldiers, however, it still shows itself as a disadvantage. Military officers often urge soldiers that they must protect their eyes. Soldiers understand the reasons for this unusually well. The reason is that, if they do not pay attention, the penalty on the battlefield can be injury or death. Conventional projectile weapons are capable of hitting behind soldiers hiding places. Taking a hand grenade and throwing it into the air, after which, it falls into a trench, it is then possible to kill and wound the soldiers hiding inside. When very close to the explosion point, even if hidden behind/251 trees, the explosion of artillery shells will also cause soldiers to be harmed. However, laser beams are still only capable of

killing and wounding soldiers directly exposed in the open. In view of this, the situation then becomes complicated. Soldiers must fire lasers. They themselves must then stand on a straight line with the target, also then putting themselves in a position to be attacked. Despite the fact that they know there are some guidance systems which soldiers must operate, most people, however, still will not go to the point of standing themselves in exposed positions.

Without doubt, on the battlefield, using high power laser beam sweeps will bring psychological pressure to bear on the enemy. This is particularly true if they are able to set on fire certain dry vegetation along the way. This will then make soldiers be careful everywhere and be on guard everywhere. However, laser beams are still not capable of burning through trees a hole to create injury to soldiers behind the tree. Due to the fact that lasers are unusually enormous, construction costs are very high, and soldiers can also very easily carry out protection and evasion against them, as a result, as far as using high power infrared lasers to act as weapons against soldiers is concerned, is also very difficult to actualize even if costs are reasonable. New models of high power lasers which operate in the visible light and near infrared areas can be very powerful in the area of injuring soldiers' eyes. However, they are still not able to kill them. As a result, at the present time, looking from the point of view of killing and wounding mechanisms, it is recognized in the end that it is still bullets which are cheaper.

13-3 Offensive Sensors

The special characteristic of modern battlefields is that electronic eyes are more useful than human eyes. The military is in the midst of being more and more dependent on electroptical sensors. This is only one portion of multiuse electronic

equipment used in command, control, communications, and intelligence (C3I--military term). In view of the sensitivity of electroptical sensors to infrared and visible light, it follows that they are easily attacked by lasers. Electronic systems and sensors themselves are easily (illegible) heated by lasers. Electromagnetic noise and high strength microwave effects are capable of creating harm. Particle beams are also this way.

The principles of attacking battlefield sensors and attacking sensors on satellites are similar. On the battlefield, the actions of various types of sensors are very different. /252 However, the main task is to aid in carrying out weapons system control. The modes of attacking sensors are capable of falling into the several types below:

(I) Use light beams strong enough to blind sensors, making them unable to track the targets they want to observe. If sensors are in the midst of guiding weapons in flight to targets, then destruction of sensors will cause weapons to miss their targets.

(II) Confuse sensors, making changes in the time periods associated with missile ignition (or explosion). It is possible to cause premature explosions not to create damage on the real target. It is also possible to block the warhead exploding.

(III) Make sensors and electronic components connected to them overload, causing components to be destroyed and weapons to malfunction, losing their way.

(IV) Make sensors themselves or optical components give rise to damage from heat or other physical causes, leading to their malfunctioning and missing the target.

(V) Strong microwave beams or charged particle beams bombarding targets produce strong electromagnetic interference, causing interior electronic components to be damaged and leading to weapons losing their direction or detonating ahead of time or not subsequently exploding.

The key point about antisensor weapons most certainly is not wanting to destroy the target, but is directed toward the most sensitive components--electronic eyes--making them unable to carry out commands or lose their operational capabilities. The sensitivity levels of different sensors are different. Most sensors are only capable of operating in a limited range of wave lengths and range of light strengths. Normally, the longer the operating wave lengths are, the more sensitive sensors are and the more fragile they also seem to be. Visible light sensors normally are made from silicon--solid and durable. However, most acute sensors, by contrast, are designed so as to be able to detect "heat" radiation with wave lengths of 8-12 microns (light waves in this wave length range are commonly emitted from objects at high temperatures). Military "night vision" systems then operate in this range because radiation emitted at night by the bodies of soldiers, vehicles, and tank engines is all in this wave length range.

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Other sensors, such as infrared, operate in even shorter wave length ranges. They are primarily used in heat seeking missiles. This type of missile is primarily used in order

to attack aircraft. The principle is that infrared sensors guide missiles in flight toward the highest temperature in the field of vision. In this way, it is then possible to make missiles fly toward jet type aircraft and destroy them. The reason is that, in the sky, high temperature gases sprayed out by aircraft have much higher temperatures than the surrounding air. However,

infrared lasers are capable of being used in order to make missiles follow mistaken flight paths. It is also possible to use them in order to destroy sensors, making missiles completely lose their way.

On board missiles, there is an extremely important system--fusing. It is used in order to detonate missile warheads. Fuses are installed beforehand. When missiles come adequately close to targets, warheads are ignited, killing or damaging the target. A number of fuses depend on optical sensors to operate. For example, on a good number of air to air missiles, optical sensors are used. They are equipped with a small, low power semiconductor laser capable of emitting short pulses. If, after pulses are sent out, they very rapidly are reflected back, the explanation is that the target is very close. If the target is close enough, the fuse will then detonate the warhead. However, the pilot of the aircraft being tracked by the missile is still only too eager to set off the fuse when the missile is far away from him, causing it not to create a threat or to cause the fuse to lose its functional capabilities. At the present time, this is the objective which electronic weapons wish to reach. Military leaders hope that lasers will play an outstanding role in the area of missile guidance associated with the help of optical sensors. In the same way, on the battlefield, it is possible to use laser guidance to make warheads not harm other targets.

Due to sensors on the battlefield playing a more and more important role, as a result, they can be attacked with particular ease by lasers. At the same time, they are also targets of attacks by tactical laser weapons. Of course, present technology is still not mature. The key point is that, among "kill and damage" mechanisms, there are a number of mechanisms which are not capable of immediately giving out feedback information on target damage status. A pilot in the midst of being followed by

heat seeking missiles--if he has a firm grasp of adequate weapons to attack the missiles--will be psychologically much more steady.

Causing missiles to explode ahead of time through fuse control is what is hoped for. Other methods for destroying sensors are still not mature enough to use on the battlefield.

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13-4 Causing Mechanical Damage

When powers exceed numerical values required to make sensors lose operational capabilities, directed energy weapons are capable of giving rise to mechanical damage in other parts of the target. Demonstrations of a number of laser weapons clearly show that they produce a certain degree of mechanical damage on targets. This left a deep impression on Pentagon military heads.

It is commonly believed that high power lasers must use time periods of 1 second to a few seconds and only then are they capable of creating "perceptible" mechanical damage. If it is possible to penetrate the atmosphere, strong charged particle beams only use one pulse and are then capable of completing this task.

Speaking only in terms of military targets, it is possible to have a number of types of fatal mechanical damage. If it is possible to make fuel tanks rupture, giving rise to fuel explosions, it is possible to destroy rockets and aircraft. Horizontal rotor blade cores on helicopters are very easy to turn soft by heating, making them ineffective and making helicopters (illegible) come down. Speaking in terms of aircraft, heating or mechanical damage are capable of making wings lose their effectiveness or cause the destruction of a number of key components (their effect during flight is on aerodynamic properties controlling the aircraft). Due to heating and

mechanical shock waves coming from laser pulses, it is possible to give rise to the destruction of windshields. Speaking in terms of modern high speed military aircraft, destruction of windshields is totally unacceptable. It is also possible to cut control wiring on aircraft. Causing the warheads of missiles or other weapons to explode ahead of time is also a case of mechanical damage.

The consequences produced by most mechanical destruction are immediately obvious. Fuel tanks are broken and aircraft lose control or helicopters (illegible) from the sky. These cases of mechanical damage are very serious in actual combat. In this way, it is not difficult to determine whether enemy equipment has already been destroyed.

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Due to laser strengths required for mechanical destruction being even higher than the strengths required to harm human bodies or electronic eyes, as a result, mechanical damage is most certainly not easy to do. Laser powers are certainly not the only problem. In the atmosphere, when laser beams increase in strength, atmospheric effects begin to manifest themselves. High power laser beams will deviate off the original target or, due to thermal expansion effects in air, (illegible) scattered off. At least theoretically, through appropriate optical technology alterations of laser output characteristics, it is possible to calibrate for some atmospheric influences. However, the problem is that this type of optical technology is still far from perfect. The degree of imperfection is perhaps even more severe than building an adequately strong laser.

13-5 Battlefield Missions

Speaking in terms of armored units, one important application of beam weapons is their ability to rapidly kill and damage multiple enemy targets (through highly directed beams). On a battlefield where friend and foe are mixed together, highly directed beams are capable of carrying out attacks on the enemy. This type of capability is in the midst of becoming more the object of people's attention with every passing day. It is in the process of being developed into a type of new weapon in order to cope with groups of enemy aircraft in rapid flight. The U.S. military is in the midst of considering applications of beam weapons on land, the sea, and in the air.

Due to lasers being able to effectively cope with the electroptical systems which are becoming more important every day among modern weapons, as a result, the U.S. Army took them and placed them in a very important position. U.S. military heads were in the midst of considering letting the Army make use of high power lasers, using them to act as front line weapons or using them in order to safeguard valuable rear area targets. These two types of purposes lead to a key distinction when designing lasers--rapid mobility. It is unusually important on the front lines. It is also very important in a number of other battlefield locations.

Any laser weapons used on the battlefield should all be mounted on a tank type vehicle. In the middle 1970's, the military had already taken medium power lasers and placed them in armored cars. In conjunction with this, they made a number of experiments in the area of performance.

Theoretically, high energy lasers are capable of firing at any target on the battlefield. Speaking in terms of lasers, the most appropriate targets are possibly fast moving or particularly fragile objects. For example: /256

(I) Enemy fighters, bombers, helicopters, and other aircraft.

(II) Short range, medium range, and long range missiles.

(III) Remote controled aircraft. These are also nothing else than the remote controled aircraft refereed to by Pentagon officials to use in battlefield observation or in carrying small weapons.

(IV) Sensors and communication equipment.

Soldiers are also one of the targets. The same as jeeps, trucks, and so on--when in an exposed position--they are simply a type of "soft" military equipment. However, U.S. military heads certainly do not believe that these are key targets. At the same time, speaking in terms of currently existing weapons, they are also very fragile targets. There are differences between heavily armored tanks and soldiers. It is not possible to hope that lasers will drill holes tens of centimeters deep in metal armor. The military is now in the midst of studying a type of armor artillery piece in order to cope with thickly armored tanks.

As far as whether or not laser weapons are able to play their roles on the battlefield is concerned, one must see if they resolve currently existing problems with capabilities as well as

levels of construction costs. Speaking in terms of the Pentagon, a few million U.S. dollars is not considered too large an expense. A new model M-1 tank can cost the Army 2 million U.S. dollars. Once lasers are put to use, firing them one time will be much cheaper than launching one missile. If laser weapons are very suitable for use, construction costs are, however, very high. In that case, it may perhaps only be possible to use them in safeguarding some unusually key places such as battlefield command centers. If construction costs are moderate and powers are very great, laser weapons are then capable of being used universally on battlefields.

Speaking in terms of any tactical weapon, compactness is very key. The ability to take high power lasers and put them into trucks the size of tanks is what is hoped for. However, this is certainly not an easy matter. Transporting the antenna for a particle beam generator or microwave weapon is a very difficult thing. A good number of technological problems wait to be resolved. Taking these types of weapons systems and putting them on the battlefield still has no military significance. /257

13-6 Beam Weapons at Sea

Certain military analysts have said that: "Speaking in terms of modern weapons, large model warships at sea are not much stronger than ducks floating around. People will not forget that, in the Faulklands War, British warships revealed the real problem when they were attacked and sunk." A number of observers even went as far as to say categorically that surface warships and aircraft carriers are already obsolete because they are too expensive and too easily attacked from the air. It is possible

to imagine that naval officers do not admit this type of view. However, they also are certainly aware that surface warships need better protection. They pin their hopes on beam weapons. Beam weapons are capable of destroying aircraft, cruise missiles, or other similar attacking missiles. Speaking in terms of warships, the attacks of these missiles are fatal.

Naval officers are unusually concerned about large scale air raids. In this type of attack, when fast flying missiles form a curtain of fire power drawing near to the target ship, conventional weapons are only capable of knocking down single missiles. There is a type of system like a gatling gun which is capable of rapidly (illegible) a hail of bullets in order to intercept missiles attacking on a large scale. Even if this is the case, naval officers do not (illegible) put much faith in them defending against this type of huge attack capability. Their concern in studying beam weapons is that they are capable of rapidly shooting down a number of attacking missiles coming from different directions and will not create damage to friendly aircraft or missiles.

Beam weapons can be fixed to warships. However, beam exits must be high enough to facilitate on open and clear field of view. Destroying missiles coming from any direction is the most important thing. If a unit does not adequately cover the entire sky, then two units must be used, even to the point of using multiple beam generators. Even if a warship is large, space is still limited. However, the problem of the huge volumes of lasers and particle beam weapons is far from being as striking as it is on aerial and space battlefields. The main projects the Navy has already developed are high energy chemical lasers and particle beams. /258

13-7 Air Force Lasers

Aircraft are much faster than warships. As a result, they are certainly not as vulnerable to attack as warships. Despite this, aircraft also face a similar series of problems. In order to defend against enemy attacks, the Air Force would rather take beam weapons and put them into fast and agile fighter planes. At the present time, the enormous volumes of beam weapons carry with them a lot of problems. The Air Force is in the midst of considering taking high energy lasers and putting them into (illegible) larger aircraft resembling transport planes (refer to Fig.13-3).

The differences between fighters and transport planes are very great. It is like comparing a racing car and a large truck.

U.S. fighters and attack aircraft at 12-20 meters long. When fulling loaded, the loads are 10-30 tons. In this, half or /259 slightly more is dead weight. The remainder is primarily fuel. They are capable of flying at twice the speed of sound, and their maneuverability is very good.

Transport planes are bulky. They fly slowly. Their speeds are below the speed of sound. C5A model military aircraft are 76 meters long. Their take off weight is 35 tons. In this, 43% is

dead weight. The Air Force has already taken carbon dioxide gas lasers with powers of 400 thousand watts and moved them onto KC-135 aircraft modified from Boeing 707's. This type of aircraft

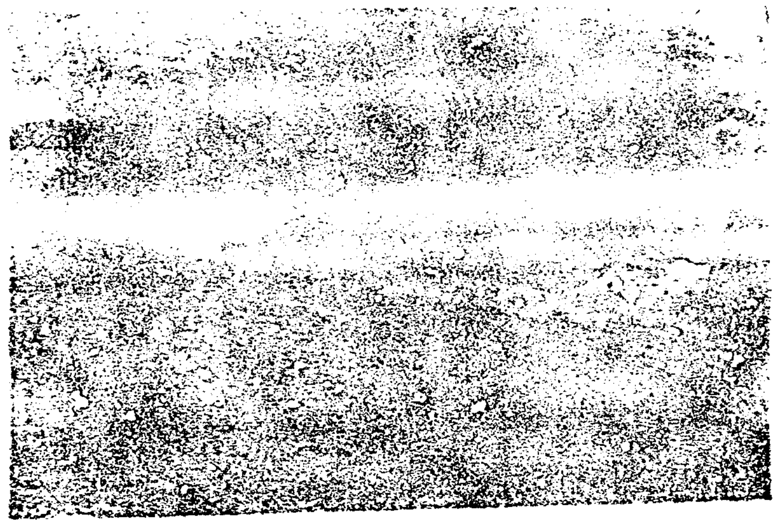

Fig.13-3 In early 1978, the U.S. Air Force took airborne laser laboratories off the ground and moved them into the air. Experiments clearly verified that using gas driven carbon dioxide lasers of 400 thousand watt powers in order to attack a real military target is no easy matter. The laser beam in the Fig. shoots out from an emitting turret on top of the aircraft. The target is in the photo on the left.

is 41 meters long. Its useful load is 136 tons. This is 3 times its weight when empty.

Taking a high energy laser and stuffing it into a fighter plane is not that easy. Fighter planes which are equipped with laser weapons are capable of launching attacks on enemy aircraft and missiles in the midst of carrying out such missions as self defense, bomber escort, as well as attack, and so on. They are also capable of handling air defense missiles. This point is unusually important. The reason is that changing the guidance systems of missiles carries with it a very great threat. Using conventional weapons, it is very difficult to block their attacks.

It is commonly believed that bombers are better suited to being equipped with lasers than escorting fighters. This is because the spacial dimensions of bombers can approximate those of transport planes. As a result, it is possible to carry large lasers. Bombers equipped with lasers are capable of destroying opposition missiles. Starting out from air defense objectives, it is possible to make beams aim at the cockpits of enemy aircraft. There are people who suggest taking this type of system and installing it on B-52 bombers, using it in order to destroy interceptors. This type of system is capable of (illegible) enemy aircraft pilot compartment glass spontaneous ignition, burning up everything in the cockpit. The U.S. Air Force revealed various types of ideas which had been tested for attacking aircraft. Among these, one method is to break up the glass of aircraft pilot compartments. The laser power densities used are 10 Joules/cm2 . This numerical value is a rough estimation. It is still smaller than the energies used in

standard experiments to measure antishock capabilities. This test uses a compressed air gun to throw a dead bird, making it reach speeds of 300 miles an hour used to simulate bird collisions with aircraft during combat. Without doubt, the /260 numerical energy values required are closely related to the forms of energy released by lasers (or birds). No matter what one says, it is almost possible to confirm that breaking pilot compartment windshield glass will cause aircraft to lose control. It is very simple. Pilots are not able to continue flying in situations where winds at speeds of several hundred miles/hour blow toward them.

When building a high energy laser, and, in conjunction with that, making beams penetrate air to the target, the difficulties met with--speaking in terms of the various military services--are different. Speaking for the Army, dust, smoke, and so on, on the battlefield; speaking in terms of the Navy, the wet environment of the ocean will increase absorption of laser beams by air. In conjunction with this, it will lead to laser (or particle beam) effective powers decreasing (speeds decreasing). Speaking in terms of the Air Force, the problem is air turbulence produced by the aircraft itself. This complicates problems such as aiming, tracking, and beam transmission. These problems are already set out in Pentagon laser and particle beam weapons plans.

13-8 U.S. Defense Department Research Plans

Pentagon studies of tactical lasers (illegible) demonstrate problems of "killing and damaging power", that is, capabilities to kill and destroy a number of important military targets, such as, the helicopters and tactical missiles of actual battlefield environments. Demonstrations of laser prototypes will have to wait until the 1990's before it is possible to realize them. It is only after such prototypes have gone through checks that it is then possible to carry out the production of laser weapons used in attacking or defending targets. As far as Pentagon predictions are concerned, it will have to wait until the late 1990's before laser weapons are capable of being applied on the battlefield.

As far as time periods being this long before it is possible to introduce them in applications is concerned, it has drawn the criticism of a number of American observers. They believe that lasers should be used on the battlefield as early as possible in order to avoid the Soviets getting ahead. Pentagon officials have said time and time again that, before it has been confirmed that laser weapons are capable of application under battlefield conditions, trying to develop this type of special weapons system would be a bit too (illegible) early. They cite as examples a series of problems--for example, effectiveness in destroying a target moving adequately fast, uncertainty about whether targets have been destroyed or not, as well as whether or not it is possible to limit countermeasures adopted by the enemy, and so on.

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In the late 1960's, gas driven lasers achieved development. After that, research was begun on laser weapons. Come the early 1970's, the Air Force then began to carry out tests on targets. Tests were carried out at the Sangdiya optical proving ground at Kirtland Air Force Base in Albuquerque, New Mexico. Observers who arrived at the base could see the burned areas caused by beams deviating away from targets. This is living proof of transmission problems given rise to by the atmosphere. Despite this being the case, Air Force scientists are still continuing research. Moreover, on 14 November 1973, a flying target was shot down using what the Pentagon called "medium power high energy gas driven lasers (that is, carbon dioxide lasers emitting powers of 100 thousand watts). The video tapes associated with these so called "Delta Project" tests have been classified right along for a number of years. However, now, at least a portion of the contents are no longer classified. In April 1982, at the Fuweikesi laser and electronics symposium, a portion of the photo (illegible) record relating to the tests discussed above were shown. In the audience there were also visitors from the Soviet Union. Despite the fact that picture quality was not (illegible), it still clearly showed, however, a target plane shot by a laser and a fuel tank set on fire. In the second experiment, the method of lasers cutting control circuits made (illegible).

The next step was then to take lasers and mount them on "Army mobility vehicles" resembling tanks. Speaking more precisely, it was taking lasers and hardening them in. The ideas of military engineers used carbon dioxide lasers built by Yafuke Aiworuite research laboratories in order to reach 30 thousand watts of power, and, in conjunction with this, taking them and mounting them into a Marine Corps LTVP-7 armored personnel carrier (refer to Fig.13-4). However, lasers in their interiors

were quite crowded leading to load bearing vehicles having to be divided into several sections and only then was it possible to suit the laser requirements. Packing in too tightly brought with it heat dissipation problems, thereby limiting system operating periods.

A 1975 mobility test vehicle actually shot down a helicopter from a considerable distance. However, this was still not able to make military heads have faith in the role of laser weapons on the battlefield. The reason was that, in this iteration of tests, target movements were (illegible) slow, and they were very easy to hit. Moreover, laser aiming systems could only be operated by hand. /262

Due to powers being too low--speaking in terms of further experimentation--technology was still not mature. As a result, this laser became a redundant spare part of no use to the Army. In the end, there was nothing else to do but move it out of the vehicles. Later, it was sent to Huntsville, Alabama's NASA Spaceflight Center and used in studying laser rocket propulsion tests.

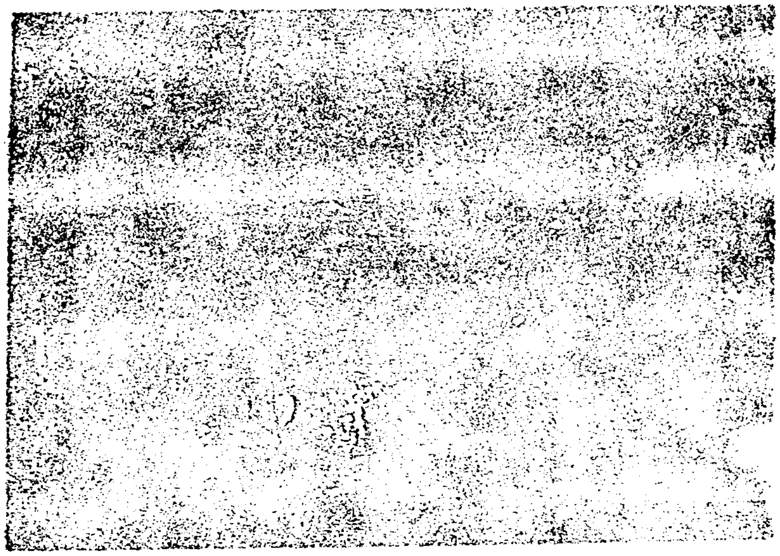

Fig.13-4 The U.S. military took carbon dioxide lasers capable of producing powers of 30-40 thousand watts (illegible) into armored cars (This [illegible] however, there were only [illegible] in order to cool this laser. [Illegible] tracking is carried out with the use of [illegible]).

In 1978, at San Juan Capistrano in the state of California, the Navy used a laser built by the TRW company with powers or (illegible) deuterium (illegible) and carried out laser weapon experiments (see Fig. [illegible] Navy ARPA chemical laser (NACL) system accounted for a large scale construction. It used an /263 aiming tracer instrument built by the Hughes Aircraft Co. This type of tracer instrument is used in TOW type antitank missile tests. The missile is also built by the Hughes Co. Speeds are just about the speed of sound. In this type of situation, lasers destroyed missile guidance systems. Moreover, in some situations, they were able to cause the missile fuses to detonate. TOW type missiles have diameters of 15cm. They are 1.2 meters long. They are certainly not targets that easy to attack. However, on the battlefield, a soldier operating wire guided missiles will discover that he himself has become an easily attacked target.

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(Illegible) air weapons laboratory carried out a series of tests. They took a gas driven carbon dioxide laser with powers of 400 thousand watts and mounted it on a KC-135 military transport plane. Lasers themselves took up the forward three compartments. The middle three compartments were power supply systems. The aft three compartments, by contrast, were spaces required by computers and other control systems. Tests began in 1974. By early 1981, laser tests were still under way. Satisfactory results had not yet been achieved.

Obviously--due to excessive self-confidence--Air Force officials made a mistake. They announced preparations to move lasers into the air, making them destroy an AIM-9 Sidewinder type air to air missile. Tests were carried out at the Navy Weapon

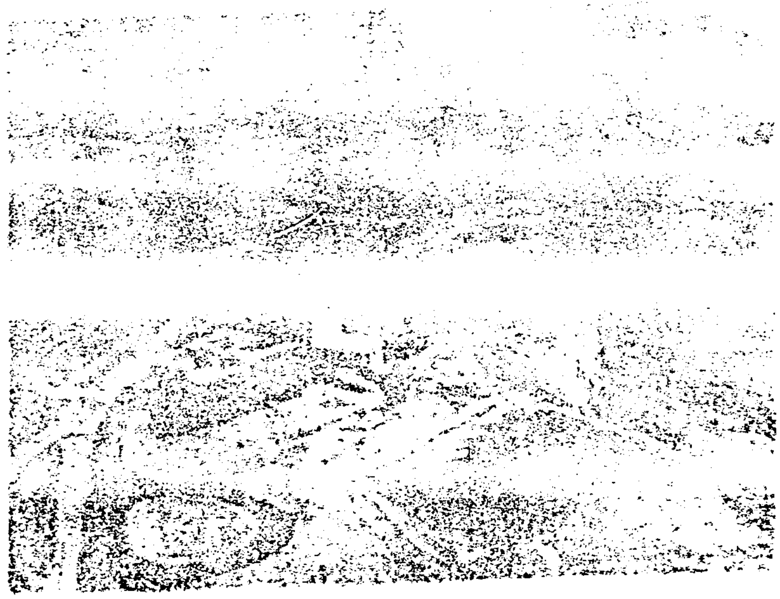

Fig.13-5 This is the U.S. Navy's united experimental project testing base in San Juan Capistrano, California. There, chemical lasers with powers of 400 thousand watts were used to shoot down "TOW type" antitank missiles. This (illegible).

Center at China Lake, California. As far as the first tests were concerned, lasers shined on targets. (Despite that fact that reports said certain damage was produced on infrared sensors) they were, however, not destroyed. In the second tests, lasers were, again, not able to destroy missiles. Reports said that this was due to "mechanical malfunctions". Pentagon officials firmly maintained that, "These tests certainly cannot be considered a true failure." They supplied some useful data. However, they were not able to carry discussions of these tests any further.

(Illegible) tests also included a series of problems. Among these were how to make lasers capable of operating in the air. Confronting laser weapon failures in tests as headlines in publications, the Air Force carried out detailed investigations on air laser laboratories. Following that, in early 1983, they again began a series of new tests. In May of the same year, the air laser laboratory finally completed its mission. First, it air fired (illegible) equipment. Following that, it destroyed five Sidewinder type missiles in a row. Test results were made public in July. At that time, Congress was in the midst of considering whether or not to cancel this project.

Not long before the test results were revealed, Brigadier General Lanbosen said: "The series of tests being carried out at the present time will be completed in fiscal 1984.

The project will be completed on schedule." (Illegible).

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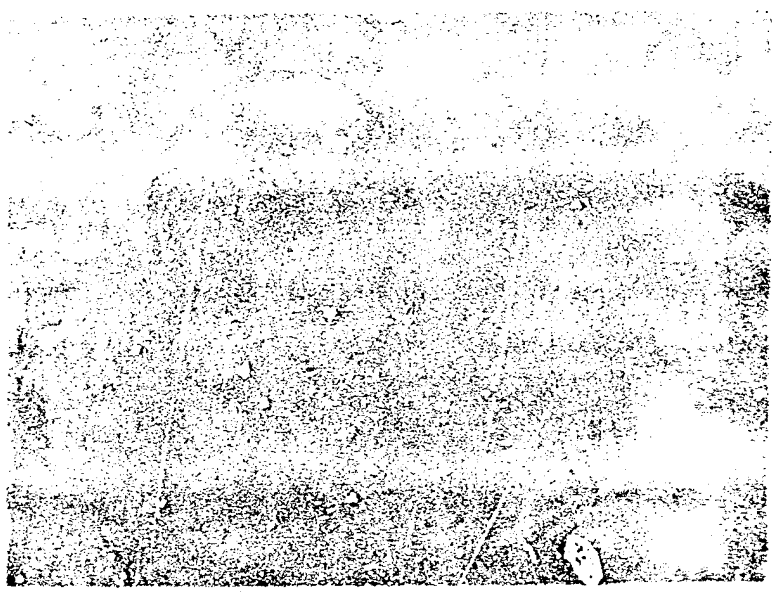
One of the leaders in proposing space based laser weapons, Senator Waluopu, said of the air laser laboratory, "In this realm, the most worthless thing is...weapons not being able to carry out missions. Test platforms are then basically not suitable for resolving the engineering problems of space lasers."

The most feasible test is the "Sea Cliff" project. The Navy is in the midst of carrying out this test at the national high energy laser center at White Sands missile range. At the present time, it is already nearing completion. The 2.2 megawatt deuterium fluoride chemical lasers used in tests are middle infrared advanced chemical lasers (abbreviated MIRACL) (refer to Fig.13-6 and 13-7). However, Congress still took the "Sea Cliff" project and cut it out of the fiscal 1984 budget. The laser projects in it were then moved to the Defense Advanced Research Planning Agency.

Fig.13-6



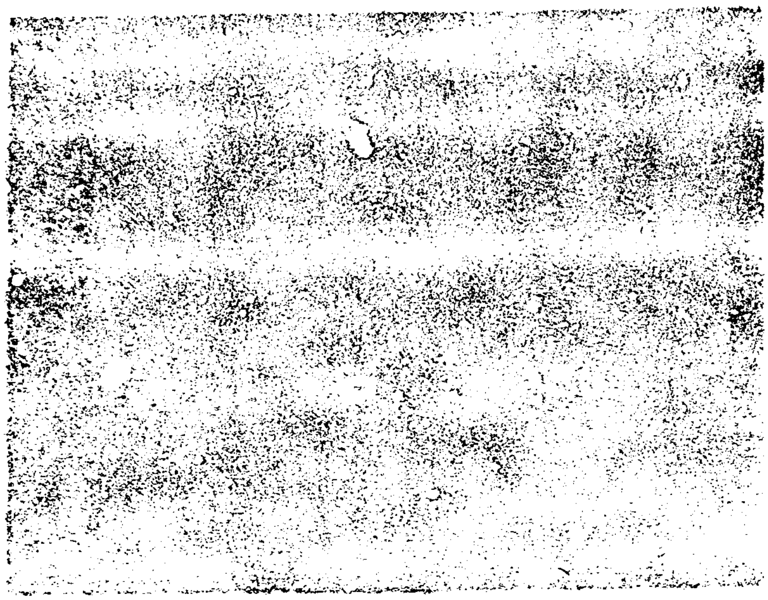


Fig.13-7 The U.S. national high (illegible) laser system test equipment (illegible) firing target (illegible).

On an advanced pin point tracking device appropriate to the handling of advanced targets and manufactured by the White Sands aircraft company, use was made of MIRACL to carry out tests. The Navy's initial objective was to collect detailed data about the destructive power of laser weapons on real military targets as well as laser weapons' capabilities to defend against concentrated attacks. Although what was stressed in them was the defense of warships against missile attacks, Brigadier General Lanbosen said, however, that new White Sands tools "will provide us with a type of basic capability. It can provide for the three services, the Defense Advanced Research Planning Agency, the Defense Nuclear Weapons Agency, and other unusually important testing systems the operation of risk branches."

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The Army is in the midst of researching its own laser weapons. The code name is "Traveler" (illegible) through carrying

out attacks on fragile targets on the battlefield (speaking in terms of lasers) in order to clearly show that it has the capability to support front line units." These tests "will let me know the technological preparations needed when operating weapons systems." However, in open situations, more detailed reports have still not been seen. Another one went through tests as laser weapons to support front line units codenamed FALW. It was taken out of the fiscal 1983 budget by Congress.

The only important particle beam test still being carried out (it is related to tactical weapons) is Lawrence Livermore Laboratories' advanced experimental accelerator project. The research associated with this project was begun under the codename "Enjoy the Inheritance at Leisure" as a Navy project used to evaluate the role of particle beams in defending warships. With regard to particle beams the primary role still remaining is in the area of tactical applications. When begun in fiscal 1979, this project was moved to DARPA. Following this type of move, the field of research problems was expanded and was also nothing else than wanting to use charged particle beams to defend a "point target"--for example, warships as well as ballistic missile launch sites, and so on.

The accelerator which this experimental project completed in 1983 at a cost of 42 million U.S. dollars is capable of producing electron beams with energies of 50 mega electron volts. The objective at present is not to see what sort of situation is created when targets are hit, but is to demonstrate whether or not it is possible for an adequately strong electron beam in the air to knock out a path. Even if experiments are just like theoretical predictions, the technologies in question are capable

of use in defending warships. In order to avoid destruction in large scale air raids, there are also a good number of things that need to be done. Physicists know that charged particle beams are capable of creating enormous damage to metal plates. However, they still do not know whether particle beam generators are capable or not--placed at an appropriate distance--of creating damage to "easily attacked targets".

13-9 Soviet Plans

The Soviet Union has its own plan to develop tactical beam weapons. However, the characteristics of the plan are still a secret. (Illegible) most (illegible) involving (illegible) weapons (illegible) are highly classified. However, in openly published Russian language Soviet scientific magazines, there are also a good number of articles with descriptions relating to high energy lasers and laser effects. The contents associated with relevant weapons were touched on rather vaguely. However, their interest in the area of high power technology is still clear and easy to see. In the past, articles relating to this area were more often seen in Russian language laser magazines than in openly published English language magazines. This fact may clearly show differences in the security system and are not necessarily explained by a relationship to the degree of effort put in.

U.S. intelligence agencies estimate, on the basis of open source data, that the effort put by the Soviet Union into the area of laser weapons is 3-5 times that of the U.S. The degree of accuracy associated with this point of view awaits deliberation. On the basis of the Reagan administration laser weapon budget, the figures appearing in 1981 reached 200 million U.S. dollars. In 1983, that grew close to double. Laser weapon supporters ceaselessly bring this figure up. In conjunction with this, they warn, "The position of U.S. leadership in the area of laser research is in the process of being surpassed." What is still not clear is whether or not the U.S. and the Soviet Union are both in the process of increasing research expenditures with the

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same vigor or there are just differences in years and that is all.

Generally speaking, comparing the scales of the two projects is quite difficult. Simply comparing costs between rubles and dollars, it is not possible to reflect the scale in the Soviet area because the Soviets' labor costs are much lower than the Americans'. Simply calculating the numbers of workers in this area is also not accurate. In summary, the Soviets are very strict about information security, and intelligence analysis is quite difficult.

There are different points of view existing within the Pentagon. In consultations released regarding the status of high power lasers, agencies responsible for directed energy projects said, "It is very clear that the Soviet Union is in the midst of concentrating quite large forces to study high power laser technology. Perhaps they have already begun to research special laser weapons systems. Moreover, we have also decided to continue, in the next few years, to take high power laser research to be one technology project. We believe that we already have a firm grasp on the key points of taking high power laser technology and turning it into laser weapons, and our decisions are correct. Despite the fact that Soviet technology in this areas is still not mature, they are, however, also in the process of turning it into laser weapons systems. In any case, we will continue our research, and, in conjunction with that, we will pay very close attention to Soviet progress in this area. It is necessary to constantly reestimate the decisions we have made."

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In the small book, "Soviet Military Power", it points out that, "The Soviets are capable of making applications to short range bases--for example, tactical defense and medium power laser weapons aimed at troops have already developed to a considerable maturity. By the middle 1980's, applications on the battlefield will be possible. By the late 1980's, the Soviets will very possibly have begun development of research on the area of applying laser weapons on the ground, on warships, and in the air."

"Aviation Week" carried its thoughts even further, reporting that the Soviets were in the midst of preparations to install high energy lasers on Jiluofu class combat cruisers being built at the Leningrad ship yards. In conjunction with that, they are planned to go into service in 1982. It was reported that the laser systems in question were capable of destroying attacking missiles within a 16 nautical mile range through attacking the sensors. It is said that these vessels are 23000 tons. With the exception of aircraft carriers, they are the largest combat vessels in the world since World War II. However, a year later, no special news had been heard with regard to this laser system. As a result, if this is not an error in communications, then it was a mistake. There is a big difference between experimental research lasers and preparing actual laser weapons to use on the battlefield. There are several technologies which may only be capable of realization after a number of more years.

The actual situation is very difficult to estimate. Looking at the problems that air laser laboratories ran into, taking lasers and employing them as weapons to use on actual battlefields still requires overcoming a number of

technological obstacles. In the current international situation, despite the Reagan administration bringing up, in a high profile manner, the need to share with the Soviet Union beam weapon technology which the U.S. has already developed to use in missile defense, it is still not possible, however, to hope that both sides will set about helping each other to jointly develop technology weapons.

Different observers see different sides of questions. Some people see the superiority of building large laser weapons, and, in conjunction with that, they say that the time to develop this type of weapon system has arrived. However, they also overlook a series of problems which exist in the processes of beams hitting targets. Other people, by contrast, only see these problems and do not see the prospects. Although, within the U.S. Defense Department, there still are no signs of a consistent viewpoint, Pentagon officials, however, seem to have certain mutual accommodations. It is believed, in the area of battlefield applications, that consideration must be given to taking those beam weapons which have problems but also have great prospects and developing them in a steady way. They assert that they are certainly not in competition with the Soviet Union but are setting up laser development projects in accordance with the principle of "advancement in technology and financial superiority". There are some people who believe that this is quite an insightful point of view. However, they have great difficulty in maintaining themselves because, when the politicians in Congress determine the budget, they are more influenced by leaks of information about what level the Soviets have reached and do not rely on cool technological estimates.

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Chapter XIV REVOLUTION IN DEFENSE STRATEGY

Beam weapons show enormous potential in the area of supplying strategic weapons of even greater power. In the past 20 years, it goes without saying that the U.S. and the Soviet Union have both put a great deal of work into this area. Several billion U.S. dollars (or rubles) have been used in developing this type of ray and explosion system. There are some systems which seemed obsolete just as they were being constructed. There are some systems which are just in the process of research and development. At the present time, there is still not a system capable of completely satisfying military strategists' projected requirements. Why beam weapons are important is because they supply completely new ways and means in the area of actualizing that type of military power required by military strategists. If it is possible to actualize this, it will give rise to huge changes in defense strategies.

The most dramatic influences on defense strategy can come from the success and development of certain types of weapons systems, that is, this type of weapons system should be able to take intercontinental ballistic missiles carrying nuclear warheads and destroy them while they are still far from the target. This is also precisely the objective the Reagan administration hopes to reach. Looking from the viewpoints of the President and high level military heads, the deterrent capabilities possessed by certain types of weapons will be much more important than their performance itself. No matter what type of technology it is, if it is relied on to make development of a certain type of weapons system successful, then, this will very greatly change the principles for mastering the military strategy competition. It will also break away from the current strategy of

mutually assured destruction. There are people who expect ultimately to make the development of military power to move from offensive to defensive technology areas.

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The current policy of mutually assured destruction is based on a consciousness that there is no effective means to defend against a powerful attack carrying nuclear warheads. Since the middle 1960's, the U.S. and the Soviet Union have been living in a balance of terror (unstable). The world's only antiballistic missile (illegible), installed on the periphery of Moscow, is not able to block a nuclear attack resembling a rainstorm, and the U.S. doe274s not have a system of that type. In the middle 1970's, the U.S. built a security defense system. However, it was taken out before long. The reason was that people believed that it was not capable of effectively carrying out a defense. In the 1972 antiballisitic missile treaty, it prohibits building missile defense systems again.

The "mutually assured destruction" strategy brought with it this type of situation: no one side dared to rashly attack the other side. Both sides knew that, even if they carried out a first nuclear strike, the other side would still be able to keep enough nuclear warheads to destroy it. Manned bombers, nuclear missile submarines, as well as intercontinental ballistic missile launch silos all had attack countermeasures. If a certain side launched a nuclear war first, both sides would be destroyed--including military installations and city inhabitants.

The "mutually assured destruction" strategy is a type of self evolving strategy. It most certainly is not a strategy voluntarily selected by military strategists. To maintain peace it was necessary to maintain the balance of terror--deterrence of nuclear attacks. This concept made Reagan and a number of other observers feel puzzled and worried. Some people among them,

after determining to opt for the use of "mutually assured destruction" strategy to act as one type of strategy reached the conclusion that nuclear offensive technology must go far in front of defensive technology. Due to not having effective methods of blocking nuclear attacks, as a result, the only defensive means is then to use nuclear retaliation in order to threaten the other side.

At that time, one idea that existed was nothing else than to build a missile defense system, that is, through ground launched missiles, destroy nuclear warhead delivery means approaching defended targets. The Soviet defensive system encircling Moscow used this type of method. The U.S. also used it in the security defense systems already (illegible) installed. This type of means has a good number of limitations. It is a type of "point" defense system because the installation of defensive missiles and huge radars in an entire area costs too much to build. Another limitation associated with protecting "hardened" targets is whether the defended targets are capable or not of undergoing a nuclear explosion right next to them. The inhabitants are basically beyond help. It is not possible to imagine that they will be able to survive very well in a nuclear explosion. Despite the fact that the Soviet Union painstakingly built (illegible) system (illegible) inhabitants avoided the influence of antimissile system fringe effects. However, even if there are a number of lucky survivors, when they come out of "bunkers", what they will face is an environment which has undergone severe damage and pollution.

In view of the inherent limitations of this type of defensive system, it is only capable of playing a limited strategic role. In the past, U.S. officials believed that this type of system could make U.S. ground based ballistic missiles survive under a Soviet nuclear attack. In 1982, before the Reagan speech requiring increased missile defense types,

Secretary of Defense Weinberger said, "As far as MX land based missile defense and survival is concerned, there is an urgent need for ballistic missile defense systems." That type of ballistic missile defense system will protect the required (illegible) weapons to execute the "mutually assured destruction strategy". As a result, it also fits the requirements of the "mutually assured destruction" strategy concept.

Pentagon officials do not believe that ballistic missile defense technology at the present time is adequate to guarantee a defense against Soviet missile attacks. They are just in the midst of researching other ways--for example, charged particle beam weapons used primarily to defend "points". However, these weapons are still very far from practical use. Even if they can make an effective defense against incoming warheads, that is simply carrying out a defense for a limited area around "hardened" targets. They can simply act as bargaining chips in setting up a strategic balance.

Assuming there is a certain type of method capable of protecting the entire nation and causing it not to suffer nuclear attack, and, if one again assumes that one side, very early on, is able to intercept most of them before the other side's projectiles reach the target, then, this is the system that President Reagan is in the process of looking for. If it is capable of realization, it is indeed capable of changing the present strategic situation.

In ideal situations, this type of defense should be perfect.

There should not be any failures. However, military specialists know very clearly that, on the real battlefield, a completely perfect system basically does not exist. There are some enemy missiles which will be allowed to penetrate the defensive net. In order to reduce as much as possible this type of oversight,

they have put forward the idea of multilayered defense. The intent is to make enemy missiles have to penetrate multilayered defensive networks (refer to Fig.14-1 and 14-2). Any missile penetrating the first defensive layer is then additionally intercepted by the second layer defensive net. For example,

the first layer defensive network can be a set of orbiting space combat stations. Before enemy missiles launch multiple warheads, that is, in missile launch booster phase, interception is done. This layer will destroy most missiles. It is assumed that it is possible to reach 90%, that is, only 100 missile slipping through out of 1000 attacking missiles. Each of these remaining missiles is also capable of launching 5 independently guided warheads toward different targets. The second layer defensive network (a number of other orbiting combat stations) carry out interception of these independently guided warheads in flight. Assuming that 90% of them are destroyed, that leaves 50 separate warheads. The third layer only needs to carry out interception of the remaining warheads. (This third layer is primarily used in carrying out "point" defense of such key strategic points as missile launching sites.)

14-1 New Problems for Strategists

Developing this type of defensive system will bring with it a series of new problems. With regard to these, military strategists have still not given answers. /275

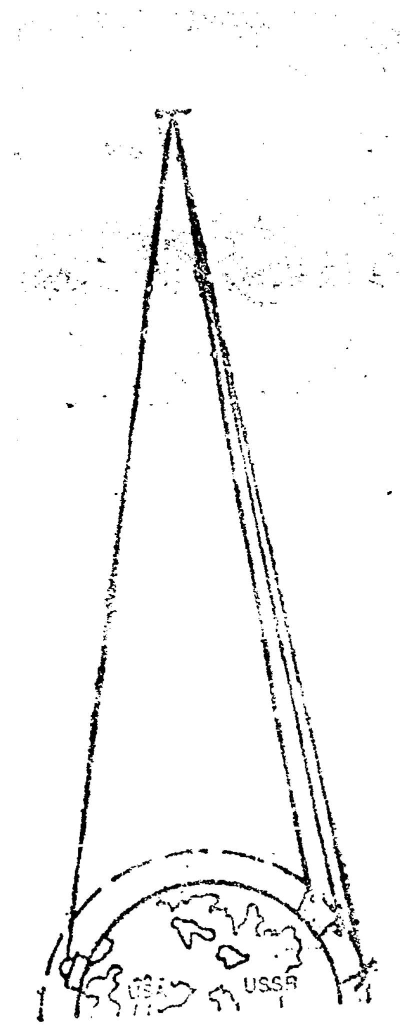

Fig.14-1 Use of Ground Based Laser Beams to Carry Out Boost Phase Interception. Beams launched from U.S. ground based lasers are reflected by relay reflector mirrors in geosynchronous orbit to combat reflector mirrors in low earth orbit. After that, combat reflector mirrors make laser beams fire against ballistic missiles. (In the Fig., the altitude of synchronous orbits, using the size of the earth as a scale, is [illegible]).

(I) How is the reliability of this type of system? That is, how many nuclear warheads penetrating the defensive net is an "acceptable" interception level?

(II) How high is the cost of reducing the offensive nuclear weapons strategy?

(III) If one side deploys to the greatest extent possible this type of system, will they then be able to guarantee themselves a decisive advantage with respect to the enemy? Moreover, is this type of advantage temporary or long term?

(IV) If another side is just in the midst of deploying defensive systems, before they actually make use of them, and, when your missiles still possess huge destructive power, will you attack them?

(V) If one side already has defensive systems, will they launch an attack before the other side possesses missile defense systems? /276

(VI) Missile defense systems should not simply be reliable in theory. What is more important is how effective are they in actual situations?

(VII) How does one side determine whether the other sides missile defense systems have not yet achieved the possession of the capability to launch attacks?

(VIII) What does one side need to do so that it is then capable of not only not allowing the spy satellites of the other side to observe the status of its experiments but also be able to carry out checks of its own missile defense systems?

(IX) How does one side make another side believe that their missile defense system possesses adequate power?

(X) If one side has defense systems, will that be a provocation to the other side? Moreover, is it possible to frighten the other side by the missile defense systems and offensive weapons it possesses?

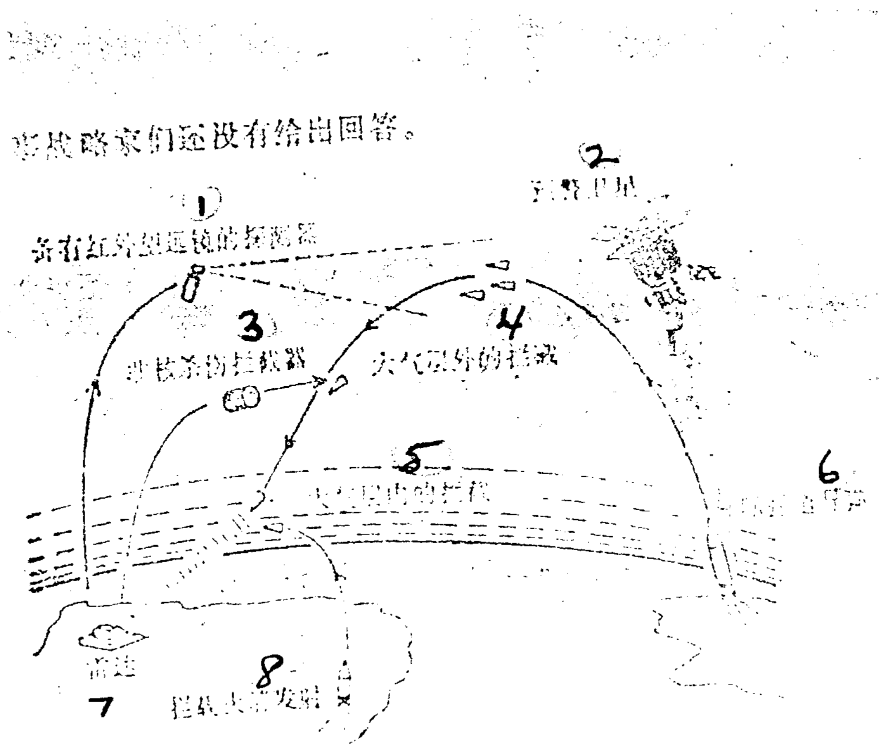

Fig.14-2 The Concept of Early, Multilayered Ballisitic Missile Defense. This and the defensive concepts imagined by the U.S. Defense Department after (illegible) propagandizing beam weapons are similar. The launch of intercontinental ballisitic missiles will be discovered by early warning satellites. The warheads launched by them must go through two defensive layers--nonnuclear killing and damaging interception devices outside the atmosphere and ground based interception devices in the atmosphere. The concept of beam weapons is similar. However, it is necessary to add space based beam weapons in order to destroy intercontinental ballistic missiles penetrating out of the atmosphere. Besides this, beam weapons should also be used to replace space based interceptors. (1) Detectors Equipped with Infrared Telescopes (2) Early Warning Satellites (3) Nonnuclear Killing and Damaging Interception Devices (4) Interception Outside the Atmosphere (5) Interception within the Atmosphere (6) Intercontinental Ballistic Missile (7) Radar (8) Interceptor Rocket Launch

(XI) If the other side has missile defense systems, to what degree will you be able to exercise forbearance yourself?

(XII) Is there a method or not of using your other weapons to overcome missile defense systems? What kind of new weapons or countermeasures are used to bring missile defense systems under control?

To put it simply, it is very difficult to give definite answers to the questions set out above. Most military heads like to debate questions brought up by the opposition. There are people who believe that the less definite the potential results of opponents launching offensives are, the smaller the possibilities of them launching offensives then also are. Due to the existence of multilayered missile defense systems, one side planning to launch a preemptive attack certainly cannot be sure of the results of their attack. Looking from the view point of strategic balance, they will perhaps realize that among 5000 warheads launched, there may be 25 that are able to reach the target. However, they will certainly not be able to know before hand which 25 will be able to hit. Moreover, most or perhaps/277 all strategic targets are protected by "point" defense systems. They are not easy to attack. When General Lanbo(illegible) was acting as the Pentagon's person responsible for directed energy projects, he said that the development of multilayered missile defense systems "will make large scale attacks not necessarily certain to produce frightful consequences. This type of capability (missile defense) will make any head of the military or government with a brain not so self-confident with regard to attacks he might want to launch. Fundamentally speaking, this type of capability will be able to curb wars."

Without doubt, in regard to discussions of nuclear strategy, they primarily concentrate on this point, that is, what are the possibilities with regard to an all out nuclear war? In this

kind of nuclear war, the U.S. and the Soviet Union will both, without doubt, launch large scale nuclear attacks against their opponent. Besides that, strategists also consider other possibilities. Besides full scale nuclear war, missile defense systems should be aggressively developed. Large amounts of material and data clearly show that the Reagan administration is in the midst of looking for a type of capability to carry out a "protracted" nuclear war--for example, when wars are capable of continuing several months, how that should be handled. One official responsible for policy told the Senate military affairs committee that what is really interesting is the question of whether or not it is possible to survive after enduring a first strike. According to the statements of this official, it is possible that this type of situation will materialize. The Soviet Union only fires part of its nuclear weapons in an attack on the U.S. Assuming that the U.S. retaliates, it then uses the remaining part to make a further attack.

Of course, a number of other possibilities still remain. Some of the possibilities among them are unusually subtle. Strategy sometimes resembles playing a game of poker. Each player carefully hides his own cards. In this, deception and counter deception is rife. Of course, military strategy also has places where it is different from playing cards, that is, its purpose is to avoid the final showdown. When the showdown is indeed reached, both sides will then come to grips and see who is the victor. In actual military strategy, the final showdown is nothing else than a war. All the players can only be losers.

In contests of nuclear strategy, "cards" are numbers of bombers and missiles. With the appearance of a new type of system capable of defending against nuclear attack and changing the quotas of "cards" and the rules of the game, any changes in rules having a decisive effect on the balance will make both sides uneasy. They are also capable of giving rise to new /278

instability. As a result, the idea of defending against nuclear attack draws peoples' attention without doubt. When encouraging the development of missile defense technology, President Reagan will use a number of lofty emotions as excuses--for example, "(illegible) isn't saving mankind better than revenge, and so on, and so on". President Reagan and other advocates of missile defense systems advocate that, through taking the balance of power and moving it from offensive weapons to defensive weapons, it is then possible to thoroughly eliminate the threat of nuclear annihilation.

14-2 Progress in Beam Weapons

There are people who believe that the basic starting point for developing any new missile defense technology is not "assured destruction" but "effective protection". Seen from this point of view, continuing to hold the doctrine of "mutually assured destruction" in order to protect the U.S. is very stupid. The reason is that this is a fragile, unstable type of balance. Military strategists are always concerned about whether or not there are other ways to release them from the quagmire of nuclear war. Certain observers put forward questions like whether or not threats to carry out devastating nuclear attacks against other nations match moral concepts. This point of view is reflected in President Reagan's speeches.

The most aggressive supporters of the development of beam weapons are a number of key U.S. military and civilian personnel who are believed to be conservatives. They firmly believe that the Soviet Union is in the process of thinking of ways of winning a victory in the current balance of forces, thereby achieving a strategic advantage. For instance, in his missile defense technology proposals, Reagan listed large numbers of Soviet military achievements. Over the last 20 years, Soviet military power has developed swiftly and violently. When their military power had already exceeded levels appropriately needed for defense, they still did not stop development. Proceeding from

misgivings about Soviet motives, the power of U.S. officialdom required the speeding up of development of new defensive systems in order to resist the Soviet military threat. /279

Reagan's interest centers on the area of ballistic missile defense capabilities and most certainly does not lie in realizing technology associated with a certain target. Indeed, seen from the strategic point of view, technology is of no importance. What is important is the defensive capabilities which it is able to supply. Beam weapons are often taken for a powerful new technology. However, it is also possible to use other means in order to reach the objective of missile defense.

Three years before Reagan gave his speech concerning the strategic defense initiative, Senator Waluopu then expressed a public recommendation about developing space based antimissile laser weapons. Obviously, he can be believed to be the first public proponent of this idea. When his article was published in "Strategic Review" printed in the fall of 1979, he declared that "technology is just in the midst of making the 'balance of terror' obsolete. Currently, technology is capable of achieving a guarantee of safety from the ballistic missile threat. He said even more clearly that, no matter which advanced country it is, it only needs to be able to grasp advanced technology, and it will then be able to achieve security."

Waluop and a number of other proponents of space based beam weapons believe that the strategy of "mutually assured destruction" is already obsolete. They see that, when the U.S. is still undecided, the Soviet Union is in the midst of setting up huge military power in order to achieve long term strategic superiority. Waluopu said that when "space defense means are grasped in our hands... , the Soviets will also master them. Moreover, we know that, when we still have not exerted maximum

efforts in order to master them, the Soviets have already done this."

In 1981, when Waluopu made a speech in the Senate, he proposed developing space based lasers as fast as possible. He said, "Our country is right at a crossroads. We have already spent a good deal--many billions have been spent--and the weapons built with the money spent are only in order to kill people. At the moment, the type of power which we are capable of making, the situation which we are capable of attaining, is nothing else than developing a type of advanced means to use in order to destroy and kill people...we have an opportunity to do our duty to the American people, that is, strive to protect them, making them finally avoid suffering the threat of nuclear butchery." /280

Other proponents who require developing space based lasers as fast as possible also put forward similar points of view. In 1981, laser technology (illegible) one Senator said, "Space based laser weapons...will mean that we lived at the finish of an era of a few score years filled with tension. To the U.S. and to the Soviet Union, technology supplied an opportunity to unwind this type of fragile strategy with its enormous destructive power. At the same time, it also made us capable of opting for the use of new, tough protective postures... High power laser development and plans for conversion to weapons make us capable of reaching this target. However, we absolutely cannot drag our feet." Of course, with regard to ballistic missile defense, there are still other conceptions. They include opting for the use of particle beams, X ray lasers, or projectile technology.

Certain ideas of Waluopu and a number of other beam weapon proponents met with (illegible) criticism from some people. For example, during the initial discussions, Waluopu said that he did not believe that space based laser weapons were provocative because they were simply enormously powerful defensive weapons.

However, a number of people inside and outside the U.S. believed that laser weapons were extremely provocative. After President Reagan put forward efforts to develop antimissile technology, the Soviet leader at that time, Yuri Andropov, immediately fired back, (illegible) accusing Reagan of planning to make the Soviet Union disarm in the face of the U.S. nuclear threat.

Waluopu also acknowledged that, in peace time, even if it is a most terrible space based laser system, it is still capable of defeating the launch of Soviet weather satellites without any effort. This is perhaps too much of an exaggeration. However, there is certainly no doubt that, if one shoots down weather satellites in motion, it will certainly make the Soviet Union feel angry. If this unfortunate target just happens to be a space ship carrying a team of cosmonauts, that would then be even more unfortunate. A number of U.S. proponents of beam weapons are obviously harboring this type of motive. They hope to anticipate Soviet development of beam weapons. The fact of the Soviets developing beam weapons has also spurred on a number of Americans. They believe that they should put even more effort into research on antimissile systems in order to avoid the Soviets taking the lead in this area. Speaking in terms of a good number of people among them, seizing the lead from the Soviets is the most urgent matter. They believe that the purpose of Soviet development of military power is to rule the world.
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The most powerful elucidation of this type of viewpoint is published in the editorials of "Aviation Week". An article published once in this magazine (illegible) Soviet development of particle beam weapons. Now retired editor Robert (illegible) took the development of particle beam weapons and compared it to playing a game of chess. "In the early 1980's, this chess match will successfully (illegible) the Soviets and tell them it is finished face to face." This statement was (illegible) in 1977.

At that time, there were also fortuitous appearances of predictions saying that certain types of Soviet beam weapons were very capable of appearing immediately in the sky. However, there were no clear signs to verify it. This type of early prediction was correct.

14-3 Warnings Coming from Certain People

A few observers outside the U.S. Defense Department held very different points of view. They believed that beam weapons are not actually that feasible. They could perhaps only destroy the currently existing strategic balance. Masheng science and engineering institute physicist, Kesita Qipisi declared: "Lasers are very difficult to turn into a practical, effective defense weapon." Qipis warned that, even if space based lasers did not play a role, it was still possible for them to cause instability in the balance of power.

Kalamuhan and Qipisi described a frightful picture of building space based laser systems. If one side is thinking of building that kind of combat station, the other side certainly will not sit and watch without taking notice. Before the enemy construction is finished, they will destroy it. Opting for preemptive attacks against defensive satellite systems will give rise to escalation of the hostility of the other side. This can lead to full scale nuclear war. Even if the other side cannot guess the effectiveness of beam weapons, they will be on guard because they have no way of confirming whether or not this type of laser weapon system is playing a role.

From a report put forward by Qipisi and three other Masheng science and engineering institute physicists-- Pamentuola, George Beikefei, and Bernard Feierde --even more pessimism than before was expressed with regard to the development of particle beams in space. The report summarized, "Developing accelerators capable of satisfying beam weapon system requirements is possible. However, as far as particle beam weapons acting as an actual system are concerned, the difficulties in their operations will be difficult to overcome." In comparison, they believed that the

outlook for building laser weapons was relatively optimistic.

Critics also had a good number of other points of view--for example, beam weapons are technologically infeasible, and so on. This includes the excessive enormity of systems put into space and the great ease of developing countermeasures to them. Here (illegible) there was not too much discussion because it would involve other than strategic questions and weapons questions.

The central opinion put forward by strategic critics is that, comparing nuclear weapons and beam weapons, relatively speaking, which construction costs are higher. If the construction costs of beam weapons are more expensive than bombers and missiles, then, the simplest strategy for dealing with nuclear missiles is perhaps to build adequate numbers of nuclear bombs to take the place of this type of defensive system.

If one expects to have 1000 warheads hit targets, then, it is possible to build 10000 warheads in order to deal with a missile defense system having an effectiveness of 90%. U.S. military heads go as far as to expect to possess even more warheads. The reason is that they are not able to confirm in the end which 1000 warheads hit targets. The final strategy will depend on the operating mode of defensive systems, that is, whether or not they are able to destroy a definite percentage of warheads as well as whether or not there is a stable optimum defensive capability. Even if this is the case, their basic way of thinking is still to build more nuclear missiles. Would this not be to pour even more gasoline on the fires of the arms race!

People who take a skeptical attitude put forward a number of important questions. They are concerned with the instability brought by the installation of missile defense systems as well as the possibility of speeding up the arms race. There are some people who hope to build defensive systems because they cannot

trust the Soviet Union. Moreover, the opponents of beam weapons also hold their own point of view. Some people among them seem to be prejudiced against any new type of weapon. Some other people, by contrast, would rather accept traditional "mutually assured destruction" strategy and are not willing to see the changes which have already appeared. The attitudes associated with proposals in regard to the Reagan development of missile defense systems are very capable of explaining the problems. There are some politicians, based on political tendencies associated with the parties and factions they belong to, who have expressed agreement or opposition to the Reagan proposals. Statements of their positions certainly are not based on the significance and value of Reagan's tentative plans themselves, but stem from political requirements. /283

What is worth pointing out is that critics who strongly oppose space based beam weapons very greatly neglect the potential role played by cruise missiles. Manned bombers and ballistic missiles launched from the ground or submarines all move in the air or the upper atmosphere. This type of missile is very easy to discover. Moreover, they are very easily attacked by conventional high power lasers (X ray lasers and neutral particle beam [illegible] emplaced in outer space orbit are not capable of effectively penetrating the atmosphere. As a result, they cannot constitute a threat to this type of missile). However, the path of cruise missiles is unusually close to the surface of the ground. X rays and neutral particle beams as well as space based lasers all seem to have no power against cruise missiles.

14-4 Beam Weapons and "First Strike"

There was a Reagan administration policy critic who criticized (illegible) development of beam weapons as the U.S. wanting to possess (illegible) the Soviet Union, and, in conjunction with that, take the lead in executing one part of this nuclear attack strategy. A book, "Nuclear War", which was passed around for reading inside the Pentagon, is this type of analysis. A first U.S. nuclear strike is most certainly not able to destroy all Soviet missiles. Approximately 10-20% will remain. These remaining missiles will be used in order to carry out retaliation against the U.S. Defense systems composed of beam weapons are, in conjunction with this, not able to handle all types of attacks. However, they are still capable of destroying attacks by the few remaining missiles of the other side after the U.S. has carried out a first strike against the Soviet Union.

The point of view discussed above appeared in the magazine "Progress" in June 1983. However, there were very few people who supported this type of strategy. The majority of Americans believed that it was immoral. If seen in accordance with the view points of certain hardline military people, this seemed, on the contrary, to have some sense to it. The reason was that they believed the Soviet Union was evil incarnate--that they were waiting right along for an opportunity to carry out a surprise attack on the U.S., and, in conjunction with that, to enslave its people. In military units, there was a so called "first strike group". This was nothing new. Beginning with the U.S. /284 possession of nuclear bombs, there had been people right along suggesting hurling nuclear bombs at the territory of the Soviet Union. Luckily, cooler heads always prevailed.

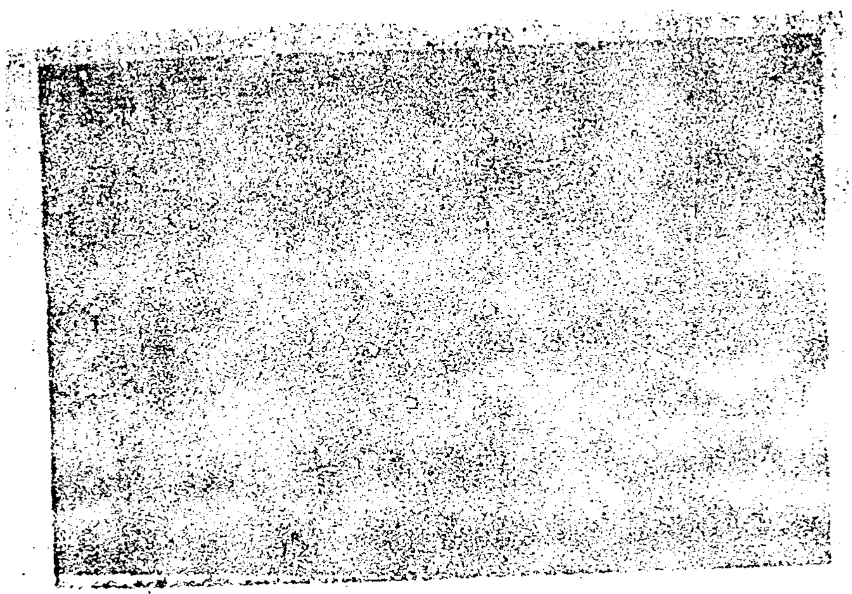

Fig.14-3 TEAL RUBY is a type of space based detection system capable of detecting and tracking flying objects close to the earth's surface.

Above, a number of questions have already been discussed. However, with regard to "counter attack" systems--X ray lasers and ground based laser combat reflectors--there is one type of consideration--only send them into space when they are needed. Up to the present time, opponents of beam weapons are still making criticisms of this type of system. Based on warning signals of enemy attacks, launching a protective system is a type of technological challenge which is difficult to handle (refer to Fig.14-3). The key here is the problem of reaction time because intercontinental ballistic missiles only require half an hour's time to fly to target. Within a half an hour, if it is not possible to complete warning signal processing, it is very difficult to imagine, within this period of time, being able to make orbiting combat stations go into space, and, in conjunction with that, begin to operate stably. Based on this type of /285 consideration, it is then necessary, before an enemy initiates an attack, to launch orbiting combat stations. It would only be in unusually tense situations where both sides felt a danger of nuclear war that this would be done. In summary, launching a defensive system will carry a series of severe consequences:

(I) The tense international situation would be aggravated further. One side will believe that nuclear war is going to occur.

(II) It will be seen as a type of actually hostile behavior. It can also be seen as a signal that the first strike is coming.

(III) A number of booster rockets launched simultaneously can be misunderstood by early warning satellites as the nuclear attack already beginning, thus impelling the other side to launch a nuclear attack.

14-5 Pentagon Positions

When carrying out votes on the suitability of beam weapons in missile defense, the Pentagon is capable of opting for an unbiased middle position. The position of U.S. officials is equivocal. They are both interested in the capabilities of beam weapons stemming from theoretical predictions, and, at the same time, when they do not see demonstrations of them possessing satisfactory effects, they have a hard time giving support to the development of this new technology. Starting with different reasoning, engineers and officials do not believe too much in predictions relating to beam weapon capabilities worked out on paper. Their reaction is cautious.

Certain people within the Pentagon seem to be reluctantly accepting this type of view point, that is, new technology will possibly lead to changes in the concept of balance of strategic forces. Although the Pentagon now asserts support for research on space based beam weapons, this is, however, helped by pressure from the Congress to put this project into practice, and that is all. The military has more intense interest in laser weapons. However, in practical terms, laser weapons, whether on the ground, the sea, or in the air, do not have revolutionary power in any case. /286

Congressional investigatory agencies--the General Accounting Office responding to Congressional requirements--investigated space based laser research projects and reached conclusions which said that adopting a cautious attitude was correct. General Accounting Office official Tangnade Dai told members of a committee relating to strategy and nuclear striking power subordinate to the Senate military affairs committee that, "Before resolving a number of important technological questions,

the fashion of believing in the roles and power of this type (system) seems premature. Even if a first generation weapons system with limited capabilities is set up, a number of technology problems still need to be resolved."

As a result, the General Accounting Office warned that it had already been said at the beginning of 1982 that limitations suffered by the technological maturity levels in the projects it was talking about were still not the same as saying that expenditures were limited. Reports said that the Defense Department had already drawn up a project preparing for the development of space based lasers, using it to act as a milestone. Within the Defense Department, priority was given to the development of laser missile defense systems. Moreover, adequate expenditures were appropriated.

Pentagon officials clearly recognized that successful development of space based laser weapons would possibly supply certain new and important capabilities and opportunities. They also recognized that the development of space based beam weapons would shock the strategic balance. Moreover, new military strategies would appear. Using the words of the Defense Advanced Research Planning Agency's Ailun Paike, "If space based laser weapons actually possess revolutionary power, we are then not obliged to take the risk of spending huge amounts of funding without any results."

The view points of the U.S. government and public with regard to space based beam weapons are of a wide variety. Generalizing from them, they fall into only two types. One type believes that relying on a protective beam weapon umbrella makes it possible for the U.S. to avoid nuclear attacks. The other type believes that making huge expenditures to set up a defense system which is not completely reliable will lead to a third World War.

The advanced research fellow of the strategic concepts development center of the National Defense College, Simiernofu, believes that the development of space based beam weapons is capable of letting people shake off the present nuclear threat. He firmly believes that, despite the fact that the development of laser weapons will not necessarily be as fast as ardent proponents such as himself hope for, in the end, however, they still must be developed. He also pays attention to the fact that the development of a new weapons system will bring temporary instability. However, his point of view is that the development of space based beam weapons is a help to breaking free from the balance of nuclear terror.

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14-6 Roles of Antisatellite Weapons

As far as the role played by antisatellite beam weapons (the greatest possibility is to use lasers) is concerned, it will not be as large as the role played by antimissile beam weapons. Although satellites play a very important role, they, however, move at high altitudes. They are not that easy to observe from the ground, like missiles. It has already been said before that, relatively speaking, antisatellite laser technology is comparatively mature. It will perhaps achieve the first applications.

The roles played by antisatellite and antimissile weapons are very different. Antimissile weapons are used in order to smash enemy nuclear attacks. However, antisatellite weapons are only used in order to destroy enemy satellites. Satellites themselves lack attack capabilities. However, making satellites lose operational capabilities will be seen by the other side as provocative behavior.

It has been brought up before that satellites have various types of different military uses. They play a role in war of supplying information by passive means--for example, communications, inspection, navigation, and so on. Even if it is peacetime, destroying the other side's satellites will still be seen as clearly provocative behavior. Just like raiding the other side's ships on the high seas, the opposition will believe that this is a very serious matter and is behavior provoking a war.

As far as (illegible) satellite movement in the highest orbits is concerned, its mission is to monitor whether of not there are signs of the other side having launched an attack. As a result, destroying early warning satellites then means that the prelude to war is just about to start. With regard to the early stages of early warning systems--for example, multiple observation satellites and redundant communications circuits--their use will give security and bring with them a certain guarantee. If several satellites simultaneously give out mistaken signals, then, this will also be taken to be enemy attacks already beginning. The reason is that the possibility of several satellites simultaneously making a mistake is extremely small. If it is a mistaken report from a single satellite, it will certainly not be definitely believed to be a signal of nuclear war. In 1982, due to detailed analysis by Pentagon officials of data erroneously put out by a spy satellite, an immediate conclusion such as "it is Soviet lasers" was not made.

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Certain observers believe that, when the international situation is tense, the development of lasers or other antisatellite weapons will increase the danger of the outbreak of war. Carnegie Melon University's Kalahaimu warned that if one side, through the use of antisatellite weapons, causes the other

side to lose operational capabilities in command, control, communications, and intelligence, then, during periods of unusually tense international situations, it will give to the other side an intense provocation, and there is a possibility, due to misreported information, of leading to the adoption of preemptive attack behavior. The causes for this type of provocation are multifaceted. Moreover, they are very difficult to control.

Hafunei of the Boston Institute's political department said, "During periods of war, the spy satellites of both the U.S. and Soviet sides are targets of attack by antisatellite systems. These satellites play an extremely important role..., satellites are not only capable of notifying of a first strike just as it is coming. They are also capable of verifying such important information as that attacks are far from starting or that attacks are not coming from another great power."

The appearance of antisatellite laser weapons aggravates people's anxieties and concerns about erroneous satellite reports (refer to Fig.14-4). It should be explained that the other side will also make the same types of efforts in order to try to achieve antisatellite weapon superiority. In conjunction with this, they will act as one important means of large scale attack. In the present international situation, the U.S. government basically just does not trust the Soviet promises to absolutely not launch an attack first. What attackers most hope for is that, when they destroy the other side's satellites, the leader's of the other side will still hesitate indecisively, delay, and not push the "attack" button. However, what they hope least for is that the other side will immediately react, with the subsequent outbreak of a full scale nuclear war.

No doubt, in a full scale nuclear war, antisatellite weapons will certainly be used. Once nuclear war has broken out, both sides will strive to destroy the communications, spy, and

navigation satellites of the other side. In peaceful environments or situations of low level conventional war, it is possible not to use nuclear weapons. However, in large scale wars, things will just not turn out this way. As far as cutting off enemy communications contact with the outside world, making navigation satellites malfunction, and making warships lose their way are concerned, these types of methods do not have much value in wars utilizing a few nuclear bombs. Some analysts believe that the capabilities of general power lasers used against satellites in strengthening support for wars play a role. /289 Moreover, high power beam weapons are capable of destroying enemy nuclear attacks. They are a help in maintaining peace.

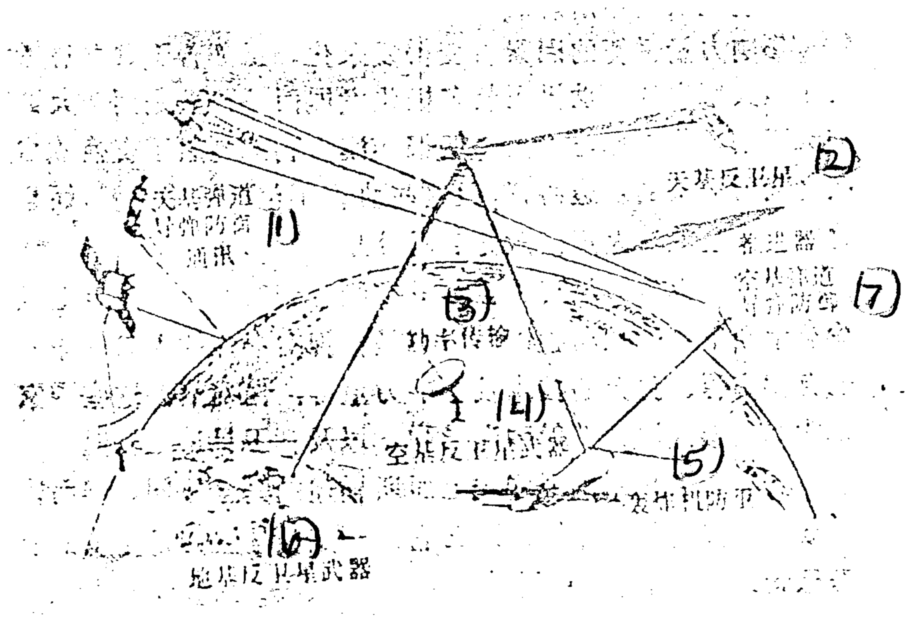

Fig.14-4 Lasers in space have very great application potential. They can be used in the weapons area. They can also be used in the nonharmful realms of communication systems and space ship propulsion devices. High power lasers--besides use in the communications area--also have broad prospects for applications in other areas. (1) Space Based Ballistic Missile Defense Communications (2) Space Based Antisatellite Propulsion Devices (3) Power Transmission (4) Air Based Antisatellite Weapons (5) Bomber Defense (6) Ground Based Antisatellite Weapons (7)

Air Based Ballistic Defense

14-7 Long Term Outlook

Looked at in the long term, if technological problems existing in antimissile weapons are capable of being overcome, then, they will play an even larger role than antisatellite weapons. Of course, antimissile beam weapons are also capable of destroying satellites. If the technology is feasible, the /290 emplacement of outer space beam weapons will appear unavoidably, unless there are breakthroughs in arms control and international detente.

In the future, the appearance of new technology will make the international situation even more complicated. Space will be colonized or industrialized. Plants, solar energy satellites as well as urban points of habitation will all be able to appear in space. The international political situation will also generate changes.

Factors influencing the balance of power will become complicated. Just as independently minded Chinese say, the world is moving toward a multipolar development and will not again be a world of only two great powers. The U.S. has already signed bilateral agreements with the U.K., West Germany, and Australia to exchange technology and laser weapon intelligence. However, these agreements do not include strategic weapons. Moreover, these nations also have no large scale laser weapon projects.

Former Pentagon official Ailun Yameng conjectures that, by the year 2032, there will be at least 10 or 15 powers in the world. Moreover, the mark of a power will be possessing large population, abundant natural resources,

strong technology, as well as military power, and so on. He firmly believes that these nations will all be capable of building nuclear weapons, launching ballistic missiles, as well as sending satellites into orbit.

Real future prospects could possibly be completely different than the description above. However, it only requires beam weapons to be mature. Then, they are definitely an important factor in setting up the balance of forces.

[TRANSLATOR'S NOTE]

The remaining pages of this document were reproduced from a book titled BEAM WEAPONS The Next Arms Race, written by Jeff Hecht. The Chinese book and the English book werefound to be so similar that the translation was stopped and these pages were added as the conclusion.

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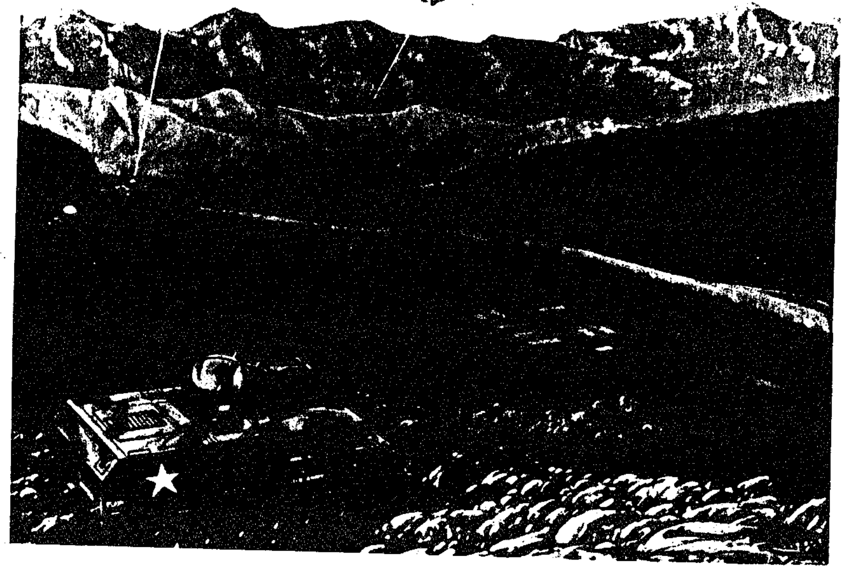
," *Astronautics & Aeronautics* **20** (11), 40–44

15 □ Beams on the Battlefield

A New Generation of Tactical Weapons

Beam weapons would undoubtedly have a serious impact on tactical warfare if they were brought to the battlefield. Yet the changes they would cause in military tactics would be much less dramatic than the changes that strategic beam weapons could cause in defense strategy. The reason is that the two types of beam weapons would do fundamentally different things. As described in the last chapter, strategic beam weapons would offer capabilities that for the most practical purposes would be new, notably ballistic missile defense. Tactical beam weapons would serve more to replace existing military equipment that doesn't perform as well as would be desired.

To understand that point, consider the similarities between the battles in World War II and those depicted in such science fiction movies as *Star Wars* and *The Empire Strikes Back*. Luke Skywalker may fly a rocket plane and fire some kind of directed-energy weapon, but his role in the action is still similar to that of a World War II fighter pilot. The Imperial Walkers in *The Empire Strikes Back* look like the result of crossing a tank with a long-legged Martian invader from *The War of the Worlds,* and they fire what look like laser bolts. Yet in battle they still play much the same role as tanks. Similarly, the laser ray guns and cannons fired by both sides are simply taking the place of rifles and artillery, respectively. The beam weapons would presumably be more deadly (they wouldn't be used in a real battle unless they were), but they are still performing the same function as the weapons used on today's battlefields.



Tank-mounted laser weapons defend an Army field command center against air attack in this artist's conception of tactical laser warfare. (Courtesy of Department of Defense.)

Zapping More Targets

From the standpoint of the Pentagon the central attraction of beam weapons is their potential for killing battlefield targets more effectively than conventional weapons. In theory, laser weapons could be used against anything that flies or moves, except heavily armored tanks. The list of potential targets ranges from individual soldiers to highly sophisticated missiles and aircraft. In practice, the interest seems to center on fast-moving or otherwise hard to kill targets with conventional weapons, or targets particularly sensitive to beam weapon attack.

At the top of the list of highly vulnerable targets are electro-optical sensors, which have become increasingly important in modern warfare. Because such devices are designed to sense visible or infrared light, they are especially vulnerable to laser attack, as was described in Chapter 13. There

are other ways to knock out sensors, including the use of electronic warfare techniques to scramble the signals they generate. However, the results can be hard to measure, and multiple layers of countermeasures may make it difficult to be sure what happened until the dust has settled. Lasers can attack such sensors more directly than electronic warfare, and in some cases it may be possible to monitor the attack by watching for reflection of part of the laser beam from the target.

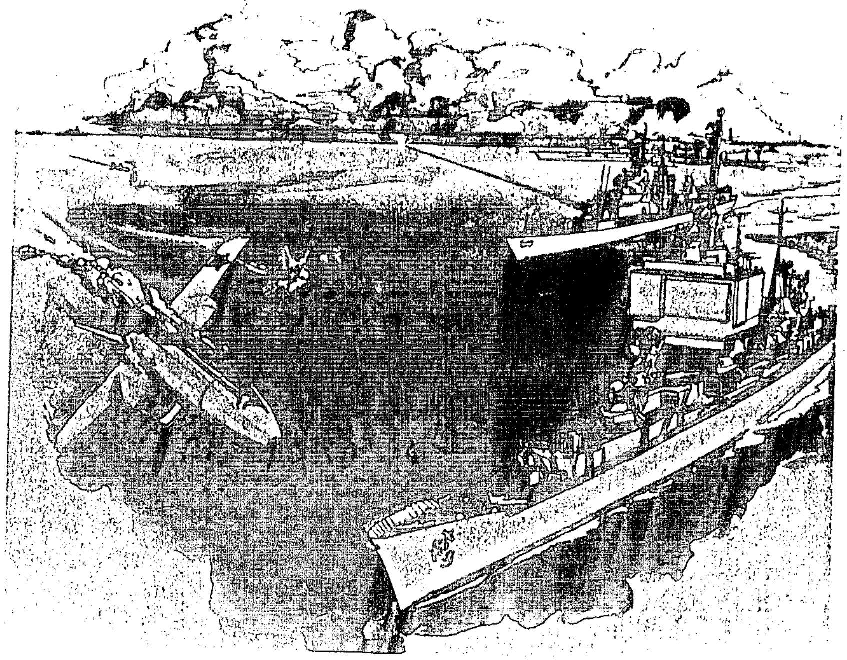
That capability complements one of the Pentagon's biggest interests: shooting down tactical missiles before they reach their targets. An amazing variety of missiles have been developed around the world, including types for launch from the air, sea, or ground at targets in any of those places. The United States armed services have some four dozen types in development, production, and/or service, and other countries have their own types.[1] When modern armies meet, there are going to be many of these highly sophisticated missiles flying through the air.

These missiles are small, fast, and deadly. Their effectiveness against targets such as fast-moving fighter planes and heavily armored tanks makes them important to disable. However, their small size and fast speed make them hard to kill with conventional weapons. Some special-purpose missiles have proven useful against such missiles, but beam weapons promise to be even faster and more precisely targetable. Laser weapons are particularly attractive because many sophisticated antiaircraft missiles are guided to their targets by infrared seekers, which could be blinded or disabled by lasers.

Military planners thus see a major role for laser weapons in ridding the sky of enemy missiles. The same weapon could be used against hostile fighters, helicopters, or other aircraft or to attack vulnerable ground targets. Because of its tightly focused beam, a directed-energy weapon would be able to zap enemy targets in the midst of a field containing friendly targets as well, a vital capability in trying to shoot down an antiaircraft missile before it could hit a friendly plane. High speed and rapid retargetability, other characteristics of beam weapons, would also be important.

Preserving the Warship

The capabilities discussed above may offer a way to protect what some observers see as the biggest sitting ducks on today's battlefield: surface-going warships and aircraft carriers. Even before the Falkland Islands War, naval commanders were concerned about the vulnerability of their warships to missile attack. The damage the comparatively weak Argentine air force was



Laser weapons zap aircraft and missiles attacking a fleet of warships in this artist's conception. The attacker at left is passing by its target on fire and out of control. Navy officials have looked at laser weapons as one way to keep the surface ship from evolving into an extinct species of sitting duck. (Courtesy of Department of Defense.)

able to inflict upon the British navy reinforced this view in the minds of some observers. Others remained unconvinced, such as *Aviation Week* editor William H. Gregory, who wrote: "The Falklands campaign did not prove anything conclusively about ships versus missiles. . . . While Exocets [French-built missiles fired by Argentine aircraft] did sink two British ships, four others were lost to iron bombs dropped by obsolete aircraft without modern countermeasures equipment. It was no test of large-carrier battle group survivability against missile swarms."[2] Later reports have indicated that the HMS *Sheffield*, Britain's most serious loss, was sunk because its computer system had been programmed to think of the Exocet as friendly and did not fire at the missile approaching the ship.[3]

Still, there are genuine reasons for concern that hostile forces able to

fire swarms of missiles from the air could attack in enough force to send eve ultrasophisticated warships to the bottom of the sea. The problem is that suc a swarm could provide more targets than existing defense systems, based o Gatling-gun-like equipment, could cope with. Either particle beams or high energy lasers might provide the rapid firing and retargeting capabilities neede to fend off such a massive missile attack. Such a defense system woul probably require sophisticated automated controls, with reaction time muc faster than a human soldier. (However, beam weapons show no immediat prospects for the other major menace to surface-going ships: submarines, which are effectively shielded from beam weapons by the water.)

The Emerging Automated Battlefield

The development of directed-energy weapons would fit in with the larger-scale development of the automated battlefield described earlier. There are no near-term plans to phase out human soldiers, but in the long term there is a continuing trend toward giving important front-line jobs to hardware.

The first generation of such weapons are called "precision-guided munitions." These include systems like "smart bombs," which automatically home in upon a spot on the target marked by a soldier on the sidelines holding a laser. They also include other systems that are remotely controlled by human operators at the rear or on the sidelines. As part of this trend, large sums are being spent on perfecting C^3I—the military code for command, control, communications, and intelligence—equipment that will let a commander run a battle more effectively from the rear.

The next generation under development are "fire-and-forget" missiles and other projectile weapons, where the only role for a soldier is to pick out the target and fire the weapon. The missile will then automatically home in on its target. As was mentioned in Chapter 10, there is even talk of completely automating the control of weapon systems so that the weapon will pick out its target, decide when to fire, and guide itself to the target. (Smart bombs can only guide themselves to targets identified by a soldier.) This leads to discussion of "intelligent" weapons[4] because, in some sense of the word, weapons with enough internal computer power to control their own firing would have to have some form of "intelligence." (This is one of the reasons why the Pentagon has been heavily supporting research in such esoteric-sounding areas of electronics and computer science as artificial intelligence.)

Beam weapons fit naturally into this trend. Those intended to fend off

massive attacks would require some degree of computerized intelligence, if only because human reaction times wouldn't be fast enough. Even slower systems designed for human control would require sophisticated pointing and tracking capabilities, to say nothing of special equipment to control atmospheric effects on the beam.

In some cases beam weapons might be used to terrify enemy soldiers. This would probably be most effective against fairly unsophisticated troops without any protective equipment, who nonetheless had some idea of the damage a beam weapon could do. However, a more sophisticated army, with access to protective gear, would soon realize what protective measures were needed and take them. In many cases it would seem that chemical or biological warfare would be more terrifying to the troops under attack.

In this context it is probably worth noting that, although there have been public claims that the Soviet Union has used chemical and biological warfare against Afghan rebels, there have been no public reports of the use of laser weapons. In practice, it may be that the toxic chemicals used in and produced by chemical lasers are so hard to handle on the battlefield that they prove to be effective chemical warfare agents against friendly troops.

The Battlefield Arms Race

The real significance of tactical beam weaponry appears to lie not in the concept itself but in what it represents—the continuing tactical arms race. Strategic nuclear missiles generally are considered the most visible part of the arms race because they're the most threatening. We in the United States do not expect our front yards to turn into battlefields, but we are afraid that nuclear missiles might land there.

That attitude is understandable. Yet in terms of dollars, in terms of numbers of programs, and in terms of technological effort and complexity, the main thrust of the arms race is aimed at tactical weapons. While the United States and Soviet Union at least devote lip service to strategic arms control (see Chapter 16), there is very little effort to control the development of tactical weapons.

According to the Pentagon, about 85% of our defense budget goes to nonnuclear forces.[5] Much of that money goes to military pay, retirement benefits, and other items far from the tactical arms race. But billions more go into an imposing arsenal of sophisticated weapons.

Comparatively small programs weigh heavily in specialized technologies. During 1982, armed forces in the noncommunist world spent some $124

million on low-power lasers for use in tactical rangefinding and target designation. That is over one-third of all sales of lasers during that year.[6] Yet it's just a tiny fraction of the billions that are being spent on research, development, production, deployment, and maintenance of high-technology weaponry.

There's no end in sight to this tactical arms race. The Pentagon is pouring billions of dollars into new battlefield hardware and concepts. Engineers are playing the conceptual chess game of countermeasures, counter-countermeasures, *ad infinitum*. If tactical beam weapons work, they will be absorbed into that continuing game without changing its essential course.

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16 □ Beam Weapons and Strategic Arms Control

Arms control has received increasing attention over the past two decades, but progress has been excruciatingly slow. The basic goal of arms control—limiting the deployment of new weaponry that would increase the danger of war without increasing anyone's national security—is as hard to argue against as the goal of peace on earth. Unfortunately, both arms control and peace are exceedingly difficult goals to attain in practice.

Diplomacy and treaty making are basic tools of arms-control negotiations, inevitably making the process delicate. The result should be an agreement that makes sure neither side gains an unfair advantage in quantity or quality of arms. With vital national interests at stake, negotiators tend to quibble over every definition and interpretation in a proposed treaty. Even such a seemingly simple task as counting the numbers of weapons possessed by each side can prove to be very complicated. That issue, in particular whether nuclear weapons controlled by European members of the North Atlantic Treaty Organization should be counted in the total of U.S. weapons, stalled 1983 talks between the United States and Soviet Union on limiting the deployment of nuclear weapons in Europe.

Over the past couple of decades arms-control negotiations have focused on strategic and nuclear armaments, which both the United States and the Soviet Union recognize as the most threatening types of weapons. Because development of missile defense beam weapons would have a dramatic impact on the strategic balance of power, such systems are emerging as a major arms-control concern. The issue is a complicated one, particularly because existing treaties mention ballistic missile defense but do not consider the possibility of beam weapons—leaving a hazy ground of wording that either side may try to interpret to its own advantage.

Both the United States and the Soviet Union clearly take the beam weapon issue very seriously. Soviet leader Yuri Andropov reacted strongly to President

Reagan's suggestions that the United States develop a missile defense system, saying that it would violate existing arms-control treaties.[1] President Reagan evidently took Andropov's criticisms seriously and responded by saying that the United States might eventually offer any missile defense technology it developed to the Soviets "to prove to them that there was no longer any need for keeping" offensive nuclear missiles.[2]

Arms-control specialists were interested in beam weapons long before President Reagan's March 23, 1983, speech. That interest is evident to anyone willing to plod through the ponderous bureaucratic prose of the annual *Arms Control Impact Statements*, which the Arms Control and Disarmament Agency submits to Congress. As far back as 1979, the Carter Administration devoted 10 pages of its 273-page report to directed-energy weapon programs.[3] The attention devoted to beam weapons has grown since then. Of the 389 pages in the edition prepared to accompany President Reagan's fiscal 1983 budget, 35 are devoted to directed-energy programs.[4] That is slightly over 1/12 the space in the book, yet the nearly $500 million President Reagan requested for beam weapons that year was a much smaller fraction (1/40) of the $20 billion requested for military research and development. (Congress eventually cut about $60 million from the Administration's beam-weapon request, and the final fiscal 1983 budget figure shown in Appendix 1 is closer to $400 million.) The directed-energy program was miniscule compared with the $258 billion the Reagan Administration requested for all military activities in fiscal 1983.

There is another indication of sensitivity: security restrictions. Two versions of the *Arms Control Impact Statements* are prepared, one classified for distribution to officials with security clearances and one unclassified for distribution to the general public. Lacking a security clearance, I receive the general distribution version in which it seems that "[deleted]" may be the most common word. Outside of the directed-energy section, it is possible to find many unexcised pages. However, only two pages in the beam weapon section don't carry the censor's "[deleted]" trademark, and one of these is the final page that contains a mere two lines. On one other page the only word is "[deleted]," another includes two "[deleted]s" and the word "systems," and a third contains three "[deleted]s" and the subheading "Program status."

Judging from the context, some of the missing material has been publically disclosed in other unclassified government publications. For example, the *Arms Control* book deletes identification of the most expensive part of the particle-beam research program,[5] which is identified as the Advanced Test Accelerator at the Lawrence Livermore National Laboratory in the Pentagon's fact sheet on particle-beam technology.[6] Similarly, the goal of the accelerator

experiments is deleted in the arms-control book but described as the demonstration of propagation of an intense electron beam through the atmosphere in the fact sheet.

The heavy-handed security policy presumably reflects the sensitivity of one of the major goals of the beam weapon program: space-based defense against ballistic missiles. Development of such a system would have serious implications for existing treaties, described below, that prohibit all but sharply limited types of defense against ballistic missiles.

The ABM Treaty

On May 26, 1972, the United States and Soviet Union signed a pair or treaties collectively known as SALT-I (for Strategic Arms Limitation Treaties). One of them is the ABM (for Anti-Ballistic Missile) Treaty, which at the time limited each country to building only two missile defense systems, one around the national capitol and the other around a missile-launching area. This was later reduced to one system per country around either site. The Soviet Union picked Moscow; the United States picked a Minuteman missile site in North Dakota but scrapped its system in 1976.

The ABM Treaty also bans "the development, testing, and deployment of all ABM systems and components that are sea-based, air-based, space-based, or mobile land-based."[7] In this case the word "development" has been subject to some special interpretation. The United States government defines it as: "The obligation not to develop such systems, devices or warheads would be applicable only to that stage of development which follows laboratory development and testing. The prohibitions on development contained in the ABM Treaty would start at that part of the development process where field testing is initiated on either a prototype of a bread-board model."[8] In short, the ban on development doesn't apply to development, but rather to testing of an already-built system. Admittedly, a stringent ban on development in the usual sense of the word would probably be impossible to enforce. Nonetheless, it is interesting to note that government officials couldn't find a different word in trying to explain how "development" had been defined in the treaty.

The treaty contains another loophole allowing "development and testing of fixed, land-based ABM systems and components based on other physical principles" that could substitute for the antimissile missiles used in the missile defense systems being developed at the time. That mention of "other physical principles" might be interpreted to cover lasers and particle beams, but the

exclusion does not include systems for use in space. It also prohibits the actual deployment of such fixed, land-based systems and components unless the treaty is modified.[9] The U.S. government also interprets the treaty as constraining the field testing of directed-energy weapons intended for certain "[deleted]" applications.[10]

Not surprisingly, the U.S. government's official position is that its beam weapons program complies with the ABM Treaty. The Arms Control and Disarmament Agency concluded that "the directed-energy related research and development efforts funded in this fiscal year 1983 budget have not more than marginal arms control effects now, [but] this technology deserves continuing attention in the future."[11] This opinion is based on plans to test the three elements of DARPA's Space Laser Triad separately, with the Alpha chemical laser and the large optics demonstration experiment staying on the ground. Tests of an integrated system in space probably would be considered a field test—at least by the Soviet Union.

The arms-control book mentions plans for mid-1980s demonstrations intended to allow a decision on whether to go ahead with "advanced development prototypes," which would be demonstrated by the early 1990s. If those prototype demonstrations work, the report continues, "laser weapons could be available in the late 1990s for selected offensive and defensive applications such as defense of ships, aircraft, high-value ground targets or satellites, destruction of ground and airborne sensor systems, and ballistic missile defense."[12]

The report does not mention what would happen to the existing treaties at that point. Actual deployment of an antimissile weapon system would require either modification or abrogation of the ABM Treaty. Proponents of the High Frontier space-based missile defense system have urged just such a course.[13] Another possibility would be trying to find a loophole big enough to accommodate a laser or particle-beam battle station.

The *Arms Control Impact Statements* book generally uses the generic term "directed-energy weapon" but at one point indicates[14] that the main concern is laser weaponry. This is consistent with the Pentagon's public position that it is too early to assess the feasibility of particle-beam weapons.

The Soviet Union seems to think that particle beams might be usable as weapons of mass destruction and has raised the issue both in public and in discussions of the Committee on Disarmament Working Group on Radiological Weapons and New Mass Destruction Weapons. One Soviet proposal would ban weapons using "charged and neutral particles to affect biological targets"[15]—that is, people. The American arms-control report does not identify any specific U.S. response to that proposal but does say that most proposed

particle-beam weapons focus their energy onto a point and hence could not be weapons of mass destruction.[16] The Soviets appear to be concerned about the interaction between an intense particle beam and the air producing what is called "secondary radiation."[17] The same thing occurs on a much smaller scale when a cosmic ray hits the atmosphere. As the energetic particle strikes atoms in the air, it can break up atoms to generate other particles or cause the atoms to emit short-wavelength electromagnetic radiation: gamma rays and X rays. At high doses this secondary radiation can be harmful to people, and the theory is that an intense enough particle beam could generate a cone-shaped shower of secondary radiation powerful enough to kill or disable any people in the way. It is far from clear that the concept could be militarily useful in practice. A powerful enough particle-beam generator might be too big to haul onto the battlefield or put into orbit. And power would be important because without enough power such a weapon might kill soldiers very slowly—hardly a useful way of fighting off an enemy.

Weapons in Space

The idea of stationing weapons in space has become a controversial one in itself. The Outer Space Treaty, which went into effect in 1967, includes some high-minded statements about the goals of space exploration to maintain international peace and security and to promote cooperation and understanding among nations.[18] Yet it puts only a few limitations on weapons in space. A careful reading shows that nuclear bombs are expressly banned from space, along with other weapons of "mass destruction." There are no restrictions that would prohibit artificial satellites from housing military bases or other types of weapons. Thus, the treaty appears to allow particle-beam and most types of laser battle stations. One exception is the X-ray laser battle station described in Chapter 6, because the nuclear bomb that would power it is expressly forbidden from space. The X-ray laser proposal would also run afoul of the 1963 Limited Test Ban Treaty, which prohibits nuclear tests in the atmosphere or space,[19] tests needed to verify the X-ray laser weapon concept.

Concern over orbiting weapons goes beyond battle stations for missile defense to include antisatellite weapons that require putting something in orbit, such as the Soviet killer satellites. The United States and Soviet Union talked about banning space-based weapons altogether in 1978 and 1979, and in 1981 the Soviets proposed a draft treaty that would ban space weapons.[20] The next year the United Nations held a conference on the exploration and

peaceful uses of outer space (UNISPACE 82), which many of the participating countries hoped would make a similar proposal. However, strong opposition from the United States led to a mere mention of "general concern" in the final report. Talks held the same year by the United Nations Committee on Disarmament also failed to produce significant action on space-based weapons.[21]

Some observers outside of the two major powers are disturbed not just by weapons in space but by all military equipment in orbit.[22] There has even been some talk of trying to keep military equipment out of space altogether. That's a noble sentiment, but as long as there are large nuclear arsenals, spy satellites can help keep the peace by making sure that those arsenals are where they belong.

Antisatellite Weapons

The role of spy satellites is recognized implicitly in the ABM Treaty, the SALT-I Interim Agreement, and the unratified SALT-II agreement. All three ban the use of weapons that might interfere with "national technical means" of verifying that the other side is complying with arms-control treaties. That strange-sounding term has not been defined formally in any international agreement but is generally taken as covering surveillance and early-warning satellites.[23] In short, "national technical means" are electronic spies, recognized in somewhat prettier words by treaties that protect them from being shot at by the spied upon.

Although the three agreements prohibit *use* of antisatellite weapons against at least some types of satellites, they do not outlaw the development, testing, or even deployment of such weapons. As far as the treaties go, laser (or other types of) satellite killers can be built, tested against target satellites intended for that purpose, and deployed ready for use. They can even track the other side's satellites. What is forbidden is to pull the trigger.[24] The United States and Soviet Union have talked about limiting or banning antisatellite weapons, but no talks are under way at this writing. The *Arms Control Impact Statements* state only that the United States "is reviewing its policy in this area."[25]

More Push for the Arms Race

As in most parts of the arms race, research on beam weapons serves to stimulate other military research. Despite the denials from the Pentagon, it

is clear that the United States and the Soviet Union are engaged in a race to develop beam weapons, a race President Reagan's interest can't help but stimulate. Each side believes (with good reason) that the other side is working on beam weapon technology. Each side seems to believe that at least some beam weapon technologies offer the potential for important military capabilities, most importantly ballistic missile defense. Thus, both sides have their own programs in directed-energy technology, with each apparently following its own development strategy.

It is hard to see anything on the horizon that might stop that race, short of a "show-stopper" type of problem that can convince both sides the whole idea is ridiculous. In theory, arms-control agreements might be used to limit development programs, but in practice that has yet to be done. Spy satellites can count missile silos and other large weapon systems, but they can't peer inside research laboratories. That would require on-site inspections of military laboratories, something neither the United States nor the Soviet Union have been willing to accept. Without some way of verifying compliance with arms-control treaties, there is little incentive to sign them in the present atmosphere of mutual distrust.

The problem with most beam weapon concepts, from an arms-control standpoint, is that development programs are not likely to produce any effects that the other side could monitor to verify compliance. The X-ray laser is an exception because it can't work without the explosion of a small nuclear bomb, which the other side *can* detect. But as long as other types of beam weapons are being tested in a closed laboratory, it is impossible to monitor development programs if security is tight enough. Without some way to verify compliance, there are no incentives for countries that don't trust each other to sign treaties limiting development programs—and then to comply with them. The same type of reasoning has led to treaties that limit the deployment, rather than the development, of missile defense systems in general.

What about prospects for limiting the actual deployment of beam weapons for missile defense? Those are hard to call because they will depend on political and technical factors yet to be defined. Neither Ronald Reagan nor Yuri Andropov are likely to be in office when the technology is ready; the views of their successors are as unknown as their identities. The technological nature of a beam weapon system for missile defense is also undefined. If it proves to be as bulky, expensive, and restricted in capabilities as critics predict, both sides might be willing to negotiate limitations, especially if they are at a rough parity in development. If, as seems likely, construction of orbiting hardware is a highly visible and lengthy process, that might add to the incentives for negotiating limitations. On the other hand it might prove very

hard to negotiate meaningful and effective limitations if the technology promises to be highly effective and not horrifyingly expensive, if one side feels that it is decisively ahead of the other, or if one or both sides are not in a mood to negotiate, for their own political reasons.

Will other countries try to get into the game? The high stakes and inherent secrecy cloud the issue, but no other countries seem as willing to make the necessary investments of money and technological resources as the United States and the Soviet Union. China might be interested. The country has been putting high priorities on both laser and space development. Yet China is still recovering from the scars of the Cultural Revolution, which caused a major hiatus in scientific and technological development.[26] China is also the one major country to have cut its military budget recently, citing more urgent needs for economic development.[27] Thus, it seems unlikely that China is an active participant in the beam weapons race.

The United States has had agreements to share classified technical information on high-energy lasers for tactical uses with four of its allies: Britain, France, West Germany, and Australia.[28] Those agreements do not cover information on strategic laser weapons, that is, those for missile defense. There are also no obvious signs that any of those four nations have strong high-energy laser programs, apparently preferring to let the United States lead the way and pay the bills. Japan has never been very active in high-energy laser development and only recently has begun building industrial lasers with continuous power levels of more than 1000 W. The Soviet Union rarely shares its advanced military technologies with its Warsaw Pact allies, and there are no signs that high-energy lasers are an exception to that pattern. The U.S. *Arms Control Impact Statements* does warn that other nations might become interested in laser weaponry once prototypes become available, but that day has yet to come, and the report notes that cost would still be a problem.[29]

What of the long-term impact on arms-control efforts? In the eyes of many observers the deployment of beam weapons for missile defense would simply be another step in the continuous arms race, with no sign of change in an overall pattern they find distressing. In some ways it might be even more disturbing because it would mark a failure of the 1972 ABM Treaty to effectively stop deployment of missile defense systems. (The construction of a pop-up system of X-ray laser weapons would be even more unsettling because it would mark the demise of two other major arms-control treaties dating from the 1960s: the Limited Nuclear Test Ban Treaty and the Outer Space Treaty. That appears to be the reason why government censors delete official indications of interest in X-ray laser weapons from virtually all un-

classified government publications.) Pessimists warn that these moves would push us further toward a dangerous instability in the balance of power.

Outside of the most vocal advocates of beam weaponry, few observers see the development of beam weapon missile defense systems as a quick cure to the threat of nuclear war. However, some observers besides President Reagan have expressed hope that strategic beam weapons might help ease a transition away from national defense policies based on threats of nuclear doom. Barry J. Smernoff of National Defense University suggests that the development of effective defensive weapons, and the shift in power from offense to defense, might help convince the great powers and their allies to reduce the sizes of their nuclear arsenals.[30] As mentioned in Chapter 14, Paul J. Nahin of the University of New Hampshire has gone a step farther and suggested that orbiting antimissile battle stations be operated by an international peacekeeping force, as a step toward dismantling strategic nuclear arsenals.[31]

Realization of those visionary-sounding hopes will require real international cooperation, not merely new technology. The alternative is a continuation of the arms race to ever-higher technological levels. As one of the staunchest of laser weapon advocates, Malcolm Wallop, has noted, "Like all other weapons in history, they would be neither 'absolute' nor 'ultimate.' "[32]

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17 □ Conclusion

Where Are Beam Weapons Going?

In many ways it is premature to try to write a conclusion to the story of beam weapons. Critical tests of feasibility have yet to be performed. Vast differences of opinion remain both on the possibility of building beam weapons and on the effect such weapons could have on military strategy and tactics. President Reagan's call for an effort to develop beam weapons for missile defense is just the opening of a debate over whether the United States should try to do so. Yet those same differences of opinion demand that some effort be made to sort them out.

Although I have never been involved in beam weapon development on an official level, I have spent enough time watching the field to fancy that I can fill in some of the "deleted" portions of government publications. I've learned which sources to trust and which ones to question. I have tried to keep my objectivity and to avoid letting personal prejudices color my judgments. I don't claim to have all the answers (no one does), but I do feel that I have a general idea of what is happening.

The answers are not clear and unambiguous; neither the world nor the technology are that simple. Beam weapons are very immature, but they do show signs of promise. Pencil-and-paper projections can be made of their characteristics, but the results differ widely. The fact is that until some critical experiments are performed, no one will be *certain* how well the technology will work. There clearly is much to be learned, and that is the job of a research and development program. It would be surprising if there were no surprises around the corner.

Assessing the Possibilities

Will beam weapons work? I've seen statements ranging from a flat "no" to a definite "yes, and soon." These conclusions come from respectable-sounding sources who have studied the question carefully. To understand something of how such widely divergent answers were reached, let's first take a look at some historical lessons.

The story of Archimedes and the mirrors in Chapter 2 is well worth remembering. Generations of eminent scholars thought the idea was ridiculous, and some of them disproved it—they thought—with pencil and paper. They were wrong. An experiment in the mid-1700s showed that the idea would work, but it was conveniently forgotten. Another experiment a decade ago again showed that the idea could work, as mentioned in Chapter 2. We will never know if Archimedes was able to overcome the practical problems of logistics and to get an adequate number of mirrors with good enough surfaces to burn the Roman ships. But we certainly know that eminent scholars can say some foolish things.

History is full of such failures of imagination. Science fact and fiction writer Arthur C. Clarke noted that and went on to formulate what he called "Clarke's law":

> When a distinguished but elderly scientist states that something is possible, he is almost certainly right. When he states that something is impossible, he is very probably wrong.[1]

In this context Clarke defines an "elderly" physicist as one over 30.

In the 1940s and 1950s a number of prominent physicists declared that intercontinental ballistic missiles and landing a man on the moon were technologically impossible. They were wrong, of course. The ICBM example was pointed out to me by Maxwell W. Hunter II during a break in a mid-1981 seminar on high-energy lasers, which I moderated for the American Institute of Aeronautics and Astronautics. As a young engineer, he had been one of the people who developed the ICBM. Now a high-level engineer at Lockheed, he was instrumental in shaping Senator Wallop's proposals for orbiting laser battle stations for use against ICBMs. There are major obstacles to be overcome with high-energy lasers, he said, but analogous barriers were overcome in the ICBM program. He predicted that high-energy laser weapons could be made to work, if the country was willing to make the needed commitment.

On the other hand more than one brainchild of Pentagon planners has succeeded only in consuming large quantities of the taxpayers' dollars. Over

$1 billion was spent between 1945 and 1961 in an effort to develop a nuclear-powered aircraft, which literally never got off the ground. There was even an apparently erroneous report in *Aviation Week* that the Soviet Union was flight-testing a nuclear-powered plane.[2] It's an example I point out to friends in the laser community, as I wonder aloud which of today's programs will in two decades be the boondoggles we knew and loved.

The commercial world has made some expensive wrong guesses of its own. One example is the Bell System's unsuccessful attempt to convince the general public that a Picturephone belonged in every home. Another was the supersonic transport, aviation's great white hope of 1970, which evolved into the white elephant of 1980. Browse through technological magazines of the late 1960s and you can find many more examples. There was, for example, a holographic tape system, which in late 1969, officials of the RCA Corp. predicted would find a $1-billion market for video playback in 10 years;[3] by 1973, the holographic system had vanished from sight, leaving only the name "Selecta-Vision," which the company would later apply to the videodisk system it finally put on the market using completely different technology nearly a decade later.

The problem is hype. Anyone trying to sell an idea is liable to get carried away in translating a bright idea into a program and promise more than he can possibly deliver. The developers of the nuclear-powered aircraft finally couldn't find a mission for the plane. The holographic videotape ran into technical problems. The same story is written over and over again in program slippages in government and industry. I would half-seriously propose Hecht's Law of Technology Marketing: "Any sales projection is an overestimate, and any marketing timetable is overoptimistic." That applies not just to industry, but also to programs sold to the government. Indeed, writing proposals urging military agencies to support research programs was once described as a special type of science fiction writing by Ben Bova,[4] a person certainly qualified to make such judgments because he was responsible for marketing the Avco Everett Research Laboratory's laser development programs to the government before leaving to become a full-time science-fiction and -fact writer, and editor of *Analog Science Fiction* and *Omni*.

Both Clarke's law and Hecht's law apply to beam weaponry. At least some of the technology—most likely infrared, visible, and ultraviolet lasers—has a reasonable shot at working. Not working according to the most optimistic timetables, but working sometime within the next couple of decades.

The pessimists seem to have their hearts in the right place in their desire to avoid further escalation of the arms race. But their analyses are so determinedly pessimistic that they can become unrealistic. Perhaps inadvertently,

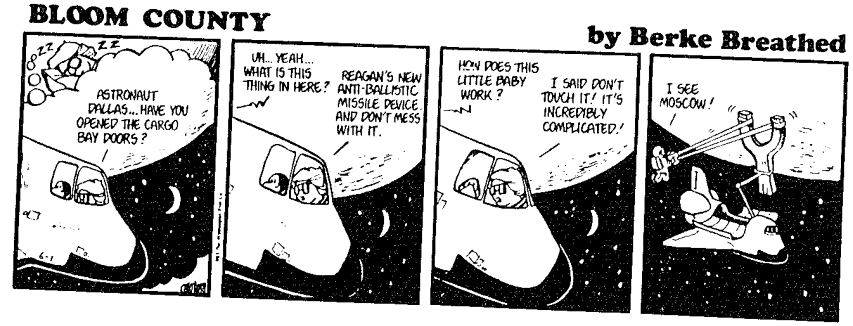
they have stacked the deck to come out with the answers they want to hear. Although the most pessimistic studies, such as those of Kosta Tsipis of the Massachusetts Institute of Technology, have gotten widespread attention in the general press,[5] they are largely shrugged off by most people active in laser weapon development. Scientists who I have come to respect complain of flawed analyses and an unwillingness to listen to critical questions, and say that information in the classified domain basically disproves the most pessimistic conclusions. There are obvious problems with some of the assumptions made in the more pessimistic studies, including selection of unrealistically small mirror diameters[6] and stationing of the hypothetical battle stations in geosynchronous orbit,[7] where they would have to shoot at targets over distances ten times longer than if they were at the lower orbits proposed by Pentagon analysts. Both types of assumptions tend to require unreasonably high laser powers, and hence vast supplies of fuel.

Proponents of beam weapons also make some reasonable-sounding points. President Reagan has advocated missile defense systems as a better strategy for protecting our country from nuclear attack than reliance on the threat of a massive nuclear counterattack. Senator Wallop has said that an antimissile laser battle station in space "threatens nothing except weapons of mass destruction."[8]

Yet proponents of crash development programs ignore the very real technological limitations and uncertainties present in all beam weapon concepts: chemical lasers, conventional short-wavelength lasers, free-electron lasers, particle beams, X-ray lasers, and microwaves. More money might speed the pace of development somewhat, but throwing billions of dollars at the problem will not put an orbiting shield of laser battle stations over our heads overnight. Without carefully planned experiments that are performed in a logical sequence, those billions of dollars could be wasted in exploring blind alleys. There are also serious logistic problems inherent in trying to vastly accelerate any large program, prominent among them is the need to train the engineers who will build the system and to develop the industrial base that will manufacture the hardware.

When will high-energy laser weapons work? The question is a complex one because the *laser* technology is the easiest part of the problem, something which is also true for most other types of beam weapons. The most severe difficulties come in getting the beam to the target and seeing that it does the needed amount of damage.

The United States and the Soviet Union both are probably close to having enough laser firepower on the ground to disable a satellite by blinding its sensors. In fact, both sides may already have that firepower. It is not at all



Beam weapons are easier to dream up than to build. All it takes is a fertile imagination, such as that of *Bloom County* cartoonist Berke Breathed. (Reprinted with permission.)

clear that existing beam-direction and fire-control systems could hit a satellite on demand. Nor, for that matter, is it clear that such lasers could do anything militarily useful. If they have to wait until an enemy satellite obligingly floats by slowly, due overhead, they would be of little practical value.

Nonetheless, the technology for building antisatellite laser weapons seems fairly close. Current satellites are easy targets, particularly spy satellites, because of the inherent vulnerability of their optical sensors to low levels of laser illumination. Because of the limited range of a ground-based laser, addition of an orbiting battle mirror or the use of an aircraft-mounted laser seems more valuable from a military standpoint. Orbiting antisatellite lasers would probably be much harder to build than those for use on the ground or in the air, although far easier than reaching the much higher powers needed for orbiting antimissile lasers. Putting an antisatellite laser into orbit would have another drawback: the actual deployment of an antisatellite weapon in orbit could be considered a provocative act by the other side.

The main limitation on antisatellite weapons may be their limited military usefulness. For better or worse, spy satellites serve a stabilizing function, reassuring each side that the other is not in process of launching an attack. Taking potshots at such satellites in peacetime, and especially during a period of international tension, doesn't make sense. The other side is far too likely to interpret those potshots as the first shots of a war and react accordingly. Once the fighting starts, antisatellite weapons could be valuable, particularly if the war is expected to last a while as in the unsettling scenario of a protracted nuclear war. But care must be taken that these antisatellite laser capabilities not be too provocative, lest they trigger action by the other side that *causes* a war.

If battlefield lasers work, there could be two generations: a first aimed at optical and infrared sensors and a second aimed at causing physical damage to the target. The first type would be easier to build but would be of limited utility. Although many battlefield weapons rely on optical and infrared sensors for guidance, you can't be sure that the missile being fired at you has a guidance system you can knock out with a laser. However, such lasers should be fairly easy to build and, in fact, may be within reach now.

Lasers capable of causing physical damage to a target would be much more desirable on the battlefield. A weapon that blew up an antiaircraft missile would be far more reassuring to the pilot of the target plane than a weapon that blinded sensors but caused no obvious harm to the missile. The laser power needed has been demonstrated, although the technology needed has yet to be packaged in a form resembling the compact and rugged gear that would be needed on a battlefield. The big problem, however, is getting the beam to the target. It is far from clear that the problems presented by the atmosphere can be tamed well enough—and at a low enough cost—for many military uses.

Recent cuts in Navy and Air Force tactical laser weapon programs seem to indicate that beam-transmission and other problems have not been solved. Although much of the impetus for the cuts has come from Congress, the Pentagon has gone along without strenuous objection. Unofficial reports indicate that the Navy's MIRACL laser worked better than the equipment intended to get its beam to the target. The Airborne Laser Laboratory also had difficulties in delivering a lethal dose of laser energy. The Navy's program is now considered dead, while the Air Force effort is being wound down. Unless these programs are replaced, which seems unlikely, only the Army will have a tactical laser weapon program—and that a comparatively modest one which Congress cut back in fiscal 1983.

The cutbacks may make it hard for developers to even match the conservative predictions in the *Arms Control Impact Statements*, that high-power laser weapons would not be ready for battlefield use until the mid- to late 1990s.[9] Antisensor lasers might be ready earlier. However, interest in laser weaponry seems to be shifting to antisatellite and antimissile applications, where the targets would be outside the beam-distorting atmosphere.

The prospects are unclear for charged particle beams for warship defense. If charged particle beams can make their way accurately through the atmosphere, if the beam can be steered precisely, and if compact, powerful systems can be developed, the technology might be on the scene in the late 1990s. Those first two "ifs" are big ones, and there is absolutely no assurance that

the answers will come out right for beam weaponry. The same considerations apply to defense of point targets against ballistic missile attack.

If beam weapons work on the battlefield, something by no means certain, their main impact would probably be to speed the pace of battle. From a human standpoint every weapon now on the battlefield takes a perceptable amount of time to reach its target. Beam weapons would not. As far as the human eye could see, they would hit their targets almost instantaneously, although laser beams probably would take a few seconds for the "kill." Such weapons would probably provide even further impetus to speed the automation of the battlefield.

Beam Weapons for Missile Defense

The type of space-based laser defense against ballistic missiles envisioned by President Reagan, Senator Wallop, and others presents a quite different set of problems than battlefield lasers. If the laser is put into orbit, there would be no need to worry about the difficulty of getting a high-energy laser beam through the atmosphere—a problem that could make laser weapons impractical on the battlefield. Offsetting that advantage is the need to make any system that goes into space extremely compact and reliable—areas in which much work remains. One technical compromise between these problems is the idea of leaving the laser on the ground and using a set of orbiting battle mirrors to redirect the beam around the globe. This approach seems to make most sense for the free-electron laser because its output wavelength could be adjusted to match "windows" of good atmospheric transmission and because the electron accelerator it requires would be very hard to get off the ground. Nonetheless, any laser-based ballistic missile defense system would also face the very serious problem of finding, tracking, and hitting a target thousands of kilometers from the laser. This last problem could prove to be the most serious.

There is a real risk that efforts to develop laser systems for ballistic missile defense will not succeed. The Pentagon has said, "we will not be seeking to develop a single system which can intercept and flawlessly defend against all missiles and all attacks. Such a system may not be possible."[10] Better capabilities may be possible with a "layered" defense in which attacking missiles would have to run a gauntlet of defenses, which might include lasers and/or particle beams as well as other weapons systems. Yet even an imperfect

defense system can deter an attack by making its outcome uncertain, as mentioned in Chapter 14. (Admittedly, a perfect system, capable of destroying all attackers, would be the ideal, but such perfection would be much more important in actually fighting a war than in deterring an attack.)

At a time when human needs around the world urgently call out for attention, developing a new generation of weaponry cannot be our first priority. Yet without some breakthroughs in international understanding, defense needs must claim some of our resources. I see enough promise in laser technology to feel that it would be foolish to walk away from its opportunities. The technology is not going to go away; it has come a long way in the past two decades, and progress is continuing around the world. We should keep on looking at the prospects for missile defense, remembering that any real payoff is likely to be a couple of decades away. At the same time I cannot see adequate reasons for a crash-priority, multibillion dollar program. The obstacles are large enough that even such a massive program would not deploy an effective laser weapon system by the end of the decade, and I am far from certain that the job could be finished by the end of the century. Such an effort would waste billions of dollars. Given the present level of technical uncertainty, I think it's premature to even try to assign a firm timetable.

There has been a growing debate over the idea of shifting the emphasis of space-based laser research from infrared chemical lasers to those emitting at shorter wavelengths. Although there are clearly advantages to shorter-wavelength lasers, I worry that a shift now might be premature. The Department of Defense has invested millions of dollars in the ALPHA chemical laser and the Large Optics Demonstration Experiment, and it would seem foolish to stop work on those programs as long as there was any prospect of getting useful results. Moreover, rapid shifts in direction of a long-term research program tend to be disruptive to the program itself, a problem shared by many other long-term government research programs that Congress funds on a year-to-year basis. And though chemical lasers clearly have their limitations, I am unaware of any that are fatal to the idea of using them in space.

There are also problems at short wavelengths. Although smaller-diameter optics can be used at such wavelengths, the optics must be made with surfaces much more perfect than needed for infrared lasers. The lasers themselves are also not well developed. The chemical oxygen iodine laser described in Chapter 4 could offer some important advantages over hydrogen fluoride, but so far high enough powers have not been demonstrated. I am far from convinced that practical weapon-scale excimer lasers can be built; so far powers fall far short of those attained with chemical lasers, and problems with internal laser physics and with damage to the optics from the short-wavelength light could

put an upper limit on output power. Free-electron lasers seem very promising in the longer term, but the technology is immature, and putting the needed electron accelerator into a satellite is likely to take a lot of work (thus the idea of sending the beam from a laser on the ground to a mirror in space). Short-wavelength lasers deserve continued attention, but not at the expense of abandoning chemical lasers.

The X-ray laser battle station is probably a weapon whose time should never come. As indicated in Chapter 6, the technology is extraordinarily difficult. The original report of the X-ray laser demonstration at the Lawrence Livermore National Laboratory generated widespread skepticism from outside observers.[11] One of the more polite descriptions of the weaponization concept was "premature," and one observer gave a blunt one-word assessment I would not repeat here. After two years of following the strange story of the X-ray laser, I remain unconvinced that X-ray laser weapons are feasible in the foreseeable future. Once again, the problem is that it's easier to build a powerful laser than to hit anything with it.

Some defense analysts seem enchanted by the notion of a "pop-up" weapon system in which the equipment needed in orbit—X-ray lasers or battle mirrors for ground-based lasers—would not be launched until they were needed. In theory, keeping this hardware on the ground or in submarines, on rockets ready to boost it into orbit, would reduce its vulnerability to enemy attack. The concept is new enough that it has gotten little critical attention, but my own analysis leaves me skeptical of its technical feasibility and worried about its strategic consequences. It is far from clear that a complex battle station can be put into orbit, stabilized adequately, and readied to zap a fleet of attacking missiles in the 30-min interval between the launch of a missile attack and the impact of the warheads at their targets. If the pop-up system has to be launched *before* warning of the actual start of an attack, that launch becomes a visible strategic maneuver. The other side can only view it as a sign of preparation for war, perhaps even as a sign of plans for a first strike. Unlike battle stations permanently stationed in orbit, pop-up systems do not seem adaptable to operation by international peacekeeping groups. The idea may deserve a hearing, but its capabilities seem to fit much better with the desire to plan a first strike than with a need to protect against one. That would only serve to increase instability.

There are other problems, too. The X-ray laser's reliance on a nuclear bomb would open up a veritable Pandora's box of issues. Existing treaties permit only small underground tests of nuclear explosives. Development of X-ray laser weapons would require other types of nuclear tests in the upper atmosphere or in space that are prohibited by the 1963 Nuclear Test Ban

Treaty.[12] Putting any nuclear weapons into orbit, even the "small" ones needed to power X-ray lasers, is flatly prohibited by the 1967 Outer Space Treaty.[13] Actual deployment of antimissile lasers would also violate the 1972 ABM Treaty.[14] In short, a serious effort to develop X-ray laser weapons would probably require repudiation of one of the foundations of nuclear arms control—the test ban treaty—if they were to be tested under realistic conditions. Going ahead and putting such battle stations into orbit would violate two other major arms-control agreements. Such actions would probably get a hostile reaction from around the world, particularly from American allies in Europe who are very sensitive to the issue of nuclear armaments. Even though the X-ray laser might be nominally a "defensive" device, the country that first deployed one in space or in a pop-up system probably would be viewed as a prime promoter of the nuclear arms race. Given the real likelihood that the system would not provide an effective defense except *after* a first strike against the other side, the program seems a good one to pass up.

It is also far from certain that neutral particle beams could serve as the basis of space-based ballistic missile defense. The problem is generating a neutral beam focused tightly enough in angular direction and with a small enough spread in particle energy that it would be able to deliver a lethal dose of energy to a target a few thousand kilometers (or a couple of thousand miles) away. The prevalent idea is to generate a beam of negatively charged hydrogen ions and pass them through a gas to strip off the extra electrons. This inevitably involves collisions, which would tend to spread out the beam. Exactly how much spreading will be produced is one of the questions the Pentagon hopes to resolve in experiments planned at the Los Alamos National Laboratory, but even if the answer is encouraging much work remains to be done.

The Pentagon has yet to decide if microwave weaponry is anything more than a fuzzy idea. Microwaves could offer some attractive capabilities for disabling electronics, but the need for very large antennas would probably make high-power microwave systems designed to "cook" targets unwieldy on the battlefield.

The Soviet Beam Weapon Program

Is there really a beam weapon gap between the United States and Soviet Union? Although there does seem to be a beam weapon race, the difference between the two sides seems more apparent than real. I base that opinion on the following three reasons:

- First, the Soviet Union historically tends toward making risky demonstrations early in a development program. The United States, in contrast, has traditionally concentated on thoroughly checking out systems to get rid of potential problems *before* a demonstration. The space race was an excellent example. The Soviet Union managed a first few spectacular shots, most notably Sputnik, but was eventually overtaken by the United States.[15] In keeping with this pattern, the Soviet Union might be the first to demonstrate (or try to demonstrate) a laser weapon, but that demonstration might not indicate a commanding lead—a possibility in keeping with comments of Pentagon officials mentioned earlier.
- The second reason is what I call the "Soviet submarine effect," the selective leaking of confidential information to the press. Years ago, defense-industry insiders noted that American press reports of sightings of Soviet submarines off the U.S. coast tended to soar whenever Congress was debating the Navy budget. The reports apparently came from Navy officials, who were trying to remind people about the importance of the Navy. Leaks can be a source of valuable information, but they can also present problems because by their nature they are almost impossible to verify. They may be accurate, they may be spurious, or they may be one sided. The latter may be the case when the source of the leak is a person who has just been on the losing side of a decision and who decides to appeal his case to the public through the press. *Aviation Week*'s coverage of particle-beam weaponry began in just that way when retired Air Force General George Keegan went public with charges of a massive Soviet program. The magazine's coverage of X-ray lasers started with an unnamed source evidently unhappy because the Pentagon was unwilling to support the program.[16] Most observers would agree that while both articles carried a core of truth, they both also suffered from exaggeration.
- The third problem is the "threat inflation" that tends to occur during intelligence gathering. The information gathered during intelligence operations inherently tends to be imprecise. Technical details may be misunderstood, conversations may be only partly overheard, future goals may be confused with present realities, and the most interesting details may not be resolved by a spy satellite image. Intelligence analysts interpreting this information have to estimate a range of possibilities. Military planners often assume the "worst" case, which seems prudent when planning how to deal with possible threats.

However, all too often worst-case estimates are transformed into seemingly authoritative reports of new equipment about to roll off Soviet assembly lines, when in reality the Soviet Union may have built only a single experimental model that doesn't work very well.

One case in point is the warning that a large Soviet space booster under development "will have the capability to launch . . . even larger and more capable laser weapons," which appeared in the Pentagon's October 1981 brochure, *Soviet Military Power*.[17] In the middle of the following year *Aviation Week* reported the Soviets were working on a booster able to put 220,000 kg (240 tons) into orbit—twice the capacity of the Saturn 5 booster the United States developed for the Apollo program.[18] However, Barry J. Smernoff points out that the arrival of that booster had been expected since the late 1960s, but that as of early 1983 it had yet to get off the ground successfully.[19]

The same type of delays seems to plague plans to launch Soviet laser weapons reported in *Aviation Week*. An October 1981 report cited "hard information" on three new Soviet spacecraft, including one which appeared to be "a laser weapon packaged for space tests." The tests were expected to be performed in weeks or months, depending on the availability of boosters needed to put the large craft into orbit. American analysts reportedly expected the tests to be of antisatellite capabilities, "but do not rule out other tests."[20] Two years later, nothing further had been reported on the test plans. Perhaps the giant satellite is waiting for the big booster to be perfected.

Impact of Strategic Beam Weapons

How would the deployment of antimissile beam weapons affect the international balance of power? What risks would it raise? And in the light of these concerns, should we go ahead with President Reagan's plans to try to develop them? The answers are not always clear and depend on such factors as how much the missile defense system would cost.

The first thing to realize is that the existing Anti-Ballistic Missile (ABM) Treaty bans the actual deployment of a ballistic missile defense system. There might be efforts to bend or interpret the wording enough to let some battle stations slip through a loophole; after all, the word "development" has been interpreted to mean something else, as noted in Chapter 16. Yet by most current interpretations, even those of the Reagan administration's Arms Con-

Europeans did not welcome President Reagan's proposal for ballistic missile defense with open arms. This cartoon, one of a series that normally covers electronics, was originally published in the British trade paper, *Electronics Times*, on April 14, 1983, just three weeks after Reagan's speech. It reflects a general uneasiness and fear that the Reagan Administration is not serious about exploring arms-control possibilities. (Courtesy of *Electronics Times*.)

trol and Disarmament Agency,[21] beam weapons intended for missile defense could not be deployed without violating the ABM Treaty. That's one point President Reagan glossed over in his March 23, 1983, speech pushing development of missile defenses.[22]

It is also important to realize that treaties are not always considered sacred by the countries that have signed them, particularly after a change in government. Many of us might consider the ABM Treaty to have power equivalent to that of law. Yet faced with concern over the possible vulnerability of the MX missile system to destruction by a Soviet missile attack, the Reagan administration has seriously considered building an antimissile system to protect MX. The fiscal 1983 *Arms Control Impact Statements* concede that going ahead with that antimissile system "could require amending the ABM Treaty or withdrawing from it."[23] Although the Reagan administration apparently put the idea of defending MX aside while officials sought a viable home for the new missile, they could revive the antimissile proposal if they failed to find another way to assure MX's "survivability."

The strategic capabilities offered by a beam weapon missile defense system would be more tempting to the military mind than mere enhanced survivability for an intercontinental ballistic missile such as MX. Thus, they would provide even stronger temptation to break—or renegotiate—the ABM Treaty. From the standpoint of nations other than the United States and Soviet

Union, renegotation would probably be much more reassuring than simple abrogation of the treaty, as it is allowed by the treaty and would indicate that the two major powers were still interested in arms control.

There is a legitimate concern that if one major power were far ahead of the other, it might try to seize a decisive advantage by orbiting a network of battle stations and using them to keep the other side from launching anything into space. That type of scenario would be dangerous because the underdog might see little alternative but to attack the battle stations during construction. However, it seems more likely that the United States and the Soviet Union would develop similar capabilities close enough in time that neither would ever have a decisive lead.[24] Also, it would take long enough to build large beam-weapon battle satellites that there would be plenty of time to talk before taking potshots. The situation could be dangerous, but it should be survivable.

The implications of X-ray laser deployment have been given distressingly little public attention. One reason may be that the pop-up X-ray laser concept is rather new. But I suspect another is that the idea has just grown, almost of its own accord, assembled from pieces of promising technology and the wish-lists of military planners, seemingly without much critical examination. That is unfortunate, because *if* the technology works, it seems likely that its reaction time would be too slow to stop a nuclear attack that was launched before it was "popped up." Thus, the defense would work only if the system was launched *before* the attack—an act that itself might precipitate an attack. Or it might be seen as part of a first strike capability, intended to wipe out only the fraction of enemy missiles which weathered the attack.

I find it very hard to put much credence in the most pessimistic of published scenarios: antimissile laser weapons obviously won't work, but that attempts to put them into space could nonetheless trigger World War III.[25] Certainly military organizations are capable of producing, and putting on the battlefield, weapons that don't work, but the flaws were not obvious to the people building the systems. In the real world military budgets are limited and can't be stretched to buy all the hardware on the "wish lists" compiled by fertile military minds. Research programs are not expected to generate lethal hardware immediately, but eventually something useful has to be produced, or advocates of other military programs will divert the money to their efforts. And if an obviously ineffective system *did* make its way into orbit, it is hard to imagine the cautious, multilayer military bureaucracies in the United States and Soviet Union doing something wildly provocative. They would more likely go through careful and cautious probing of capabilities to decide what to do about it.

Seeking the Best Approach

At this point, far from the reality of beam weapon battle stations, it is hard to sort out the scenarios and pick out a best course. Beam weapons might not work at all, though it seems far too early to reach such a conclusion. Antimissile systems might prove so expensive, or so limited in effectiveness, that the United States and Soviet Union would willingly accept limitations on their deployment, much as they did a decade ago in agreeing to the ABM Treaty itself. Although it would probably be impossible to verify restrictions on development of beam weapons, limits on deployment should be verifiable. Large satellites are easy to watch, and even pop-up systems could be monitored to the extent we can count submarine-launched ballistic missiles.

If antimissile beam weapons prove to be both affordable and effective, it would be desirable to negotiate treaties covering their deployment, which at the same time would lead to a phasing down of nuclear armaments. It might even be possible to create some sort of international peacekeeping organization to operate the defensive satellites, something like the concept proposed by Paul Nahin described in Chapter 14. Of course, safeguards would be necessary, perhaps even elaborate ones, to make sure that the peacekeeping force would serve to protect every country in the world, not just particular ones. It could be something as simple as making half the satellites American and half Soviet, which together would provide a worldwide defense, but separately would be unable to defend (or attack) adequately. Realizing such a goal will not be easy, but it would be far better than another round of arms race.

I would like to think that such a goal would be attainable by the time beam weapons capable of ballistic missile defense have been developed. I fear it is not attainable now. President Reagan's words are full of high-spirited ideals, as exemplified by his offer to share U.S.-developed missile defense technology with the Soviets.[26] Unfortunately, the reality of the Reagan administration's actions have fallen far short of those lofty ideals, with more effort devoted to rattling sabres than to making peace. Soviet leaders, too, have been strong on rhetoric and weak on substance. Instead of trying to negotiate seriously about arms control, the two countries seem to be putting most of their efforts into scoring propaganda points and finding excuses to avoid substantive talks. Thankfully, time remains to deal with the beam weapon issue, time that should bring new generations of leaders in both the United States and Soviet Union. We can only hope the new leaders will be up to the challenge.

If space-based beam weapons can provide missile defense, they would tip the strategic balance of power to the defense. Like any transition, this would bring some uncertainty and instability. Some danger would be inevitable, but there is also danger inherent in the present nuclear balance of terror. If the great powers can cope with the challenge of a transition to a strategic defense, the result could be a stabler world. The transition to a powerful defense might, as observers like Barry Smernoff hope, devalue nuclear arsenals enough that the United States and Soviet Union would be willing to dismantle theirs.

Major uncertainties would have to be overcome to reach that optimistic conclusion. Technological barriers would have to be overcome. The United States and Soviet Union would have to change their defense strategies. The two countries would have to negotiate changes in the existing ABM Treaty, without scrapping the whole framework of arms control. National leaders would have to raise their goals beyond short-sighted self-interest toward an ultimate demilitarization of the world that in the long term is the only thing which can provide security to all the people of this planet. We can only hope that such action is not impossible.

A defense-based strategic balance is not enough by itself. There is no assurance that it could be maintained as long as there is a continuing arms race. New technology alone cannot end the arms race. History warns us that there is no such thing as an "ultimate" weapon. In 1917, after seeing the airplane go to battle in World War I, a saddened Orville Wright wrote: "When my brother and I built the first man-carrying flying machine we thought that we were introducing into the world an invention which would make further wars practically impossible."[27] A generation later, the scientists who built the atomic bomb would voice the same futile hopes.

If beam weapons are merely another round in the arms race, they will be followed by a new generation of weapons with countermeasures designed to foil beam attack. Cruise-missile technology might be extended to longer ranges, as long as the low-flying missiles could keep out of the range of antimissile beams. More bombs would be built. Bigger beam weapons would be developed in response, and the cycle would go on.

The best we can hope is not that beam weapons will end the arms race, but that they will buy us the time we need to end it. The problem lies not in the technology, but in ourselves. It lies in the inability of the United States and Soviet Union to develop a mutual respect and trust for each other. We need to learn that we are not enemies but neighbors on a small planet with different ways of life. We need to learn to tolerate each other and to avoid

trying to force our wills on others. Alas, those tasks seem far harder than building arsenals of beam weapons.

Given these realities, I see little alternative for now but to continue working on beam weapons. But at the same time we—both the United States and the Soviet Union—must strive as well to build the mutual understanding and respect that can lead to a peace far more meaningful than one imposed by the fear of each other's arsenals. If humankind can develop new technology but not better ways of understanding others, we will be only children, playing with ever more dangerous toys.

References

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2. John Tierney, "Take the A-plane," *Science* **82,** Jan/Feb 1982, pp. 46–55, gives an excellent account of the nuclear aircraft episode. The fundamental problem was that the program took on a life of its own, even without a discernable mission for such a plane.
3. The RCA holographic system is mentioned in: Brian J. Thompson, "Holography Technology," in Ernst Weber, Gordon K. Teal, and A. George Schillinger, eds, *Technology Forecast for 1980* (Van Nostrand Reinhold, New York, 1971), p. 168.
4. Ben Bova, guest of honor speech at Boskone XIV, a February 1977 science fiction convention conducted in Boston by the New England Science Fiction Association.
5. I suspect that the most widely read article critical of laser weapons is Kosta Tsipis, "Laser weapons," *Scientific American* **245** (6), 51–57 (December 1981); the article has been influential because of *Scientific American*'s prestige. Because of this highly visible publication, reporters seeking a critical view of laser weaponry to balance their stories often turn to Tsipis.
6. The worst example that comes to mind is the assumption that a 1.4-m (4.6-ft) mirror would be used with a chemical laser; in Michael Callaham and Kosta Tsipis, *High-Energy Laser Weapons: A Technical Assessment* (Program in Science and Technology for International Security, Massachusetts Institute of Technology, Cambridge, Massachusetts, November 1980), p. 46. A 2.4-m (8-ft) mirror has already been built for NASA's space telescope, though it cannot handle high laser powers.
7. See, for example, Richard L. Garwin, "Ballistic missile defense (BMD) silos and space," popular version of paper presented at March 1982 meeting of the American Physical Society in Dallas. The idea of putting a battle station in geosynchronous orbit is attractive because it would remain over one point on the globe, but the high cost of putting it in such a high orbit, and the long distances involved, are generally considered prohibitive.
8. Malcolm Wallop, "Opportunities and imperatives of ballistic missile defense," *Strategic Review*, Fall 1979, pp. 13–21.
9. Arms Control and Disarmament Agency, *Fiscal Year 1983 Arms Control Impact Statements* (U.S. Government Printing Office, Washington, D.C., March 1982), p. 300.
10. Donald L. Lamberson, plenary talk on Department of Defense Directed Energy Program, presented May 17, 1983 at Conference on Lasers & Electro-Optics, Baltimore; quote is from printed version supplied to reporters.

11. See, for example, Jeff Hecht, "The X-ray laser flap," *Laser Focus* **17** (5), 6 (May 1981), and Jeff Hecht, "X-ray laser controversy," *New Scientist* **92,** 166 (October 15, 1981).
12. Text of the treaty appears in: Bhupendra Jasani, ed, *Outer Space—A New Dimension of the Arms Race* (Oelgeschlager, Gunn & Hain, Cambridge, Massachusetts, 1982), pp. 368–369.
13. *Ibid.*, pp. 370–374.
14. *Ibid.*, pp. 375–379; there are also separate statements of understanding.
15. For a history of the space race, see: Richard Hutton, *The Cosmic Chase* (Mentor, New York, 1981).
16. The particle-beam controversy opened with Clarence A. Robinson, Jr., "Soviets push for beam weapons," *Aviation Week & Space Technology*, May 2, 1977, and was followed by a series of follow-up pieces. The X-ray laser work was revealed in Clarence A. Robinson, Jr., "Advance made on high energy laser," *Aviation Week & Space Technology*, February 23, 1981, pp. 25–27, which was followed by a long silence, evidently because of the sensitive nature of the leak.
17. Department of Defense, *Soviet Military Power* (U.S. Government Printing Office, Washington, D.C., 1981), p. 79.
18. "Soviets outspending U.S. on space by $3-4 billion," *Aviation Week & Space Technology*, July 19, 1982, pp. 28–29.
19. Barry J. Smernoff, "The strategic value of space-based laser weapons," *Air University Review*, Mar/Apr 1982, pp. 2–17.
20. "Washington roundup," *Aviation Week & Space Technolgy*, October 5, 1981, p. 17.
21. Arms Control and Disarmament Agency, *op. cit.*, p. xv.
22. The text of President Reagan's talk appears in "President's speech on military spending and a new defense," *New York Times*, March 24, 1983, p. A20.
23. Arms Control and Disarmament Agency, *op. cit.*, p. viii.
24. Sometimes hysterical-sounding warnings that the United States is dangerously behind the Soviet Union in developing beam weapons have been made by a few advocates of a massive defense buildup, but some observers without a budgetary axe to grind hold that the U.S. is ahead or at least even, despite the supposedly greater Soviet effort. For example, Barry J. Smernoff *(op. cit.)* holds that the United States has a clear lead in space development that can be carried over to space-based lasers. A. M. Din of the University of Lausanne in Switzerland also believes that the United States will probably win out in development of beam weapons; see: A. M. Din, "The prospects for beam weapons," in Bhupendra Jasani, ed, *Outer Space—A New Dimension of the Arms Race* (Oelgeschlager, Gunn & Hain, Cambridge, Massachusetts, 1982), pp. 229–239. As was mentioned earlier, gloomy prophecies of potent Soviet beam weapons orbiting the globe seem to be nowhere near fulfillment.
25. See, for example, Michael Callaham and Kosta Tsipis, *op. cit.*
26. Benjamin Taylor, "US could offer ABM to Soviets, Reagan says," *Boston Globe*, March 30, 1983, p. 1 & 7.
27. Quoted in C. D. B. Bryan, *The National Air and Space Museum Vol 1: Air* (Peacock Press/Bantam Books, New York, 1982), p. 90.

Appendix □ The Beam Weapons Budget: A History

History of funding for directed-energy programs through the Pentagon, based on information supplied by the Department of Defense. The sharp increase in DARPA's laser funding reflects interest in space-based lasers. All figures are in millions of dollars.

	Prior	FY1977	1978	1979	1980	1981	1982	1983	1984[c]
High-energy lasers:									
Army	$153.7	*	*	17.3	20.3	18.8	22.9	44.3	50.4
Navy	283.8	*	*	33.8	35.3	38.3	60.9	65.4	75.3
Air Force	448.5	*	*	101.3	91.2	70.6	108.7	102.2	133.5[a]
DARPA	231.4	*	*	30.8	48.8	64.0	108.1	128.8	172.6
Test Range[b]	20.1	*	*	*	8.2	14.5	40.2	33.9	36.9
Laser totals	1,103.7	*	*	183.2[d]	203.8	206.2	340.8	374.6	468.7
Particle beams									
Charged beam experiments:									
DARPA (SEESAW)	27.0	—	—	—	—	—	—	—	—
Navy (Chair Heritage)	8.8	5.3	7.1	—	—	—	—	—	—
DARPA	—	—	—	12.0	23.4	29.0	26.7	28.5	33.0[e]
Neutral beam experiments									
Army	—	4.4	3.8	4.3	4.1	—	—	—	—
DARPA	—	—	—	—	—	4.3	5.8	4.5	[e]
Technology base:									
Air Force	—	0.5	0.8	1.7	2.0	7.8	8.5	13.0	13.0
Army	—	—	—	1.7	2.0	0.3	0.6	1.0	1.9
Navy	—	—	—	—	—	2.0	2.4	3.7	1.5
Other[f]	—	—	—	—	—	—	—	—	2.0
Particle beam totals	35.8	10.2	11.7	18.0	29.5	43.4	44.0	50.7	51.5

* Total included under "PRIOR".
[a] Includes $36.1 million for space-laser technology.
[b] The High-Energy Laser National Test Range at the White Sands Missile Range, which is treated as a separate budget item.
[c] Reagan administration proposal as of February 8, 1983. Congressional revisions were not completed when this book went to press.
[d] Does not include funding for High-Energy Laser National Test Range during fiscal 1979.
[e] DARPA request for fiscal 1984 includes both charged and neutral beam experiments.
[f] Support expected to come from the Army Ballistic Missile Defense Systems Command.

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